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A credit-based theory of the currency risk premium[☆]

Pasquale Della Corte[a,*], Alexandre Jeanneret[b], Ella D.S. Patelli[c]

[a] *Imperial College London and CEPR, Imperial College Business School, South Kensington Campus, London SW7 2AZ, United Kingdom*
[b] *University of New South Wales, UNSW Business School, High St., Kensington, NSW 2052, Australia*
[c] *University of British Columbia, Sauder School of Business, 2053 Main Mall, Vancouver, V6T 1Z2, Canada*

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ABSTRACT

This paper uncovers a novel component for exchange rate predictability based on the price difference between sovereign credit default swaps denominated in different currencies. This new forecasting variable – the credit-implied risk premium – captures the expected currency depreciation conditional on a severe but rare credit event. Using data for 16 Eurozone countries, we find that the credit-implied risk premium positively forecasts the dollar-euro exchange rate return at various horizons. Moreover, a currency strategy that exploits the informative content of our predictor generates substantial out-of-sample economic value against the naïve random walk benchmark.

1. Introduction

Investors holding international government bonds face two major sources of risk. They bear, first, the risk of a potential depreciation of the local currency and, second, the risk of bond value erosion caused by a deterioration in sovereign creditworthiness. These sources of risk are highly intertwined as sovereign defaults are commonly accompanied by large currency depreciation (e.g., Reinhart, 2002; Na et al., 2018).[1] Also, this interaction has fundamental asset pricing implications for investors, as such events tend to occur in bad economic times (e.g., Augustin et al., 2020). We may then presume that currencies that are expected to depreciate severely in times of default are particularly risky and should deliver higher excess returns. We lack,

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* Corresponding author.
E-mail address: p.dellacorte@imperial.ac.uk (P. Della Corte).

[1] Specifically, Reinhart (2002) shows that the probability of a severe currency depreciation around a sovereign default is about 84% for a sample of 58 countries between 1970 and 2002. Herz and Tong (2008) show that debt crises Granger cause currency crises in a sample of 108 emerging countries over the 1975-2005 period, while Mano (2013) shows, over the 1873-2008 period, that currencies fall on average by 17.6% during the default year and by 29.2% compared to five years earlier. Na et al. (2018) use data for 70 countries for the period 1975-2013 and report that the median exchange rate depreciates by 45% in a three-year window around a default event. Related literature finds that countries with higher sovereign credit risk, proxied by sovereign credit default swaps, experience a significant currency depreciation (e.g., Della Corte et al., 2022).

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however, a theoretically-motivated measure of the risk premium associated with this tight relation between currency depreciation and sovereign default, as well as empirical evidence on its implications for exchange rate predictability.

This paper attempts to fill this gap in the literature in two respects. First, we develop a simple theory that uncovers a novel component for exchange rate predictability labeled as the *credit-implied risk premium*. This component adds to the *quanto-implied risk premium* of Kremens and Martin (2019), upon which our theory builds. While the quanto-implied risk premium captures the expected covariation between currency returns and frequent but small changes in US market conditions, the credit-implied risk premium reflects investors' expectations about excess currency movements in times of rare but severe events abroad, such as a sovereign default. This risk premium compensates investors for a currency depreciation conditional on default *in excess* of what is predicted by the traditional uncovered interest rate parity condition. Second, we empirically assess the out-of-sample exchange rate predictive ability of our novel risk premium component using economic criteria, thus overturning the general wisdom that exchange rates are well approximated by a naïve random walk model (e.g., Meese and Rogoff, 1983; Engel and West, 2005).

We measure expected currency depreciation conditional on default by exploiting a unique feature of the sovereign credit default swap (CDS) market, i.e., sovereign CDS for the same entity, maturity, and restructuring clauses are typically quoted in various currencies. Specifically, CDS contracts provide insurance against different risks depending on the currency denomination. A long position in a country's CDS quoted in local currency protects a US investor against default in that country, whereas a long position in the same CDS but quoted in dollars provides an additional hedge against the risk of a local currency depreciation upon default. Since the probability of default underlying a CDS quoted in different currencies is the same, under no arbitrage, the difference in CDS prices must reflect investors' expectations about the relation between the local currency and default.[2] Forward-looking CDS prices become then the critical ingredients to derive the expected local currency depreciation conditional upon sovereign default, which is the primary determinant of our credit-implied risk premium.

The Eurozone is a perfect setting for our study because most member states have a liquid market for CDS quoted both in dollars and euros (Augustin et al., 2020). In addition, the price difference between dollar-denominated and euro-denominated CDS has been fairly large for several Eurozone countries with the unfolding of the European sovereign debt crisis, as illustrated by Fig. 1. For example, Spain's one-year CDS premium quoted on January 2, 2012, was worth 339 basis points per annum in dollars but only 266 basis points per annum in euros. Armed with daily CDS premia on 16 Eurozone member states quoted in both currencies between August 2010 and April 2019, we compute a daily credit-implied risk premium for each member state. We then construct an aggregate measure of the credit-implied risk premium for the Eurozone by weighting countries with their outstanding debt. In essence, the credit-implied risk premium reflects the expected euro depreciation conditional on a sovereign default in the Eurozone, which varies substantially over the sample period. A sovereign default event, however, may not necessarily happen in our sample and, in this case, the difference in CDS prices would reflect the possibility of peso events (e.g., Burnside et al., 2011). If investors expect a possible sovereign default in the Eurozone, this risk should be then reflected in the future dollar-euro exchange rate return even if no such events materialize in our sample.

We test our theory by investigating the predictive ability of the credit-implied risk premium for the dollar-euro exchange rate, which is the most liquid currency pair with a daily turnover that exceeds half a trillion dollars (e.g., BIS, 2019). We find that the credit-implied risk premium positively predicts future dollar-euro exchange rate returns at any horizon between one week and one year, beyond the interest rate differential (Fama, 1984) and the quanto-implied risk premium (Kremens and Martin, 2019). This finding is robust to controlling for global foreign exchange volatility and liquidity (e.g., Menkhoff et al., 2012; Karnaukh et al., 2015) as well as portfolio-based currency factors (e.g., Lustig et al., 2011). At the one-month horizon, a one-standard-deviation increase in the credit-implied risk premium is associated with a positive exchange rate return of 7.9% per annum. We extend our analysis to emerging economies with available CDS contracts quoted both in local currency and US dollar (e.g., Mexico, Russia, South Africa, and Turkey). We uncover statistically significant evidence that a country's credit-implied risk premium positively predicts future exchange rate returns in a panel setting after accounting for currency and time fixed effects.

The credit-implied risk premium also generates tangible out-of-sample economic gains to an investor exploiting active portfolio management. Following Fleming et al. (2001), among many others, we design an international asset allocation strategy whereby a US investor allocates her wealth between a dollar-denominated bond and a euro-denominated bond while using the credit-implied risk premium to predict the exchange rate return. We evaluate the performance of mean-variance strategies rebalanced weekly using non-overlapping observations. We find that a strategy based on the credit-implied risk premium generates a substantial amount of out-of-sample economic value that outperforms the naïve random walk model. Specifically, a risk-averse investor is willing to pay more than 200 basis points per annum for switching from a naïve portfolio strategy to a competing one that exploits information of the credit-implied risk premium. The profitability of our strategy survives reasonably high transaction costs.

In sum, a currency carries a greater risk premium when investors expect a more severe depreciation upon sovereign default and, thus, our credit-implied predictor

[2] Alternatively, it is possible to estimate expected currency depreciation from sovereign bond data, but this approach is less straightforward. It requires extrapolating credit risk from debt financial instruments written on the same entity with the same maturity and in at least two currencies. Government bonds respecting these constraints are rare, especially for industrialized countries that tend to issue debt in their own currency.

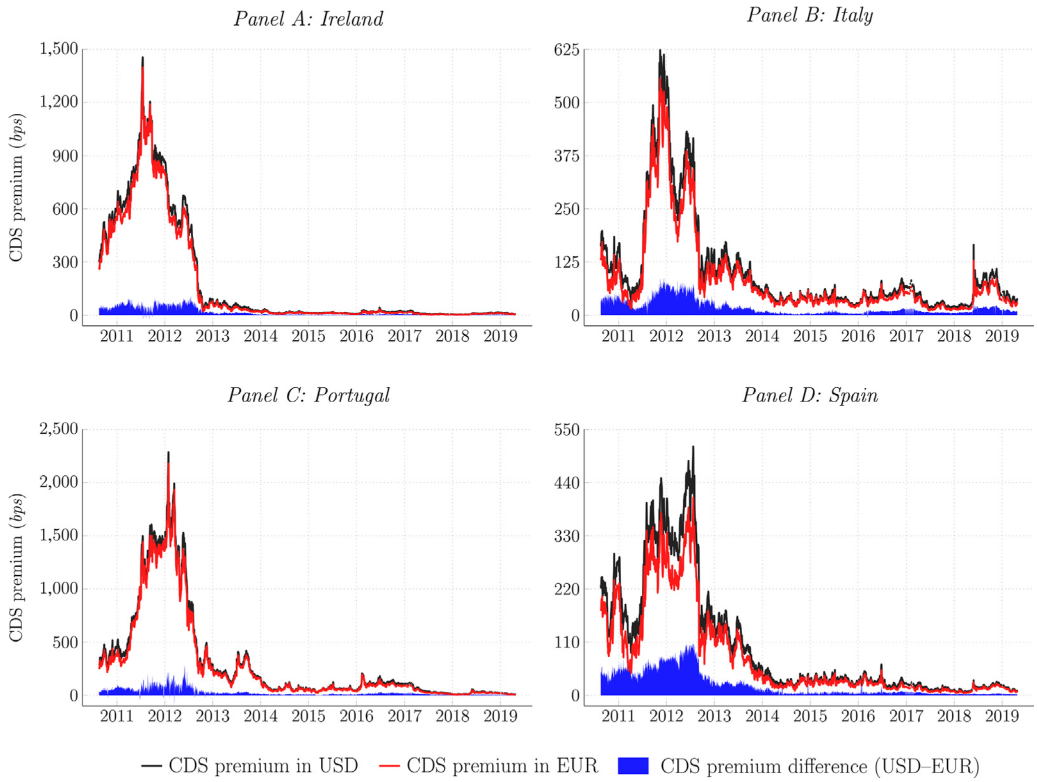

Fig. 1. Sovereign CDS premium by currency denomination. *Note:* This figure plots one-year dollar-denominated and euro-denominated sovereign credit default swap (CDS) premia of selected Eurozone member states in basis points (*bps*) per annum. The shaded area denotes the difference between CDS premia. The sample consists of daily observations between August 2010 and April 2019 from IHS Markit.

contains valuable information for exchange rate predictability. We provide evidence that our results are not due to alternative explanations. First, we can rule out that changes in the credit-implied risk premium merely reflect variations in global currency risk premia (Lustig et al., 2011), as we do not observe any predictability for non-euro currency pairs. Second, we provide empirical evidence that our predictor is distinct from the quanto-implied risk premium (Kremens and Martin, 2019) and sovereign risk, as both risk measures differ fundamentally from our predictor in terms of their economic, financial, and monetary determinants. We thus confirm our theory that the quanto-implied risk and the credit-implied risk premia coexist and span different information. Sovereign risk and the credit-implied risk premium also complement each other, as the former captures the probability of default while the latter reflects the expected currency movements *conditional* on default. Third, one may argue that the difference between euro-denominated and dollar-denominated CDS premia on the same underlying entity could be attributed to dealers' credit risk, as opposed to the interaction between default and depreciation. However, we find that our results are robust to controlling for dealers' counterparty risk. Fourth, we confirm that the predictability is not an econometric artifact arising from the persistence in returns, as our results also hold using weekly non-overlapping observations. Finally, we conduct a country-level study and conclude that the predictability of the credit-implied risk premium is concentrated among the economically most important Eurozone economies, such as France and Germany, which rules out the possibility that some small countries with less liquid CDS contracts drive our findings.

Our work relates to a growing literature on the currency denomination of sovereign CDS. Mano (2013) is the first to exploit the difference between sovereign CDS denominated in dollars and local currency.[3] He concludes that a model with segmented markets can generate predictions consistent with the empirical evidence on the currency depreciation during sovereign defaults. Du and Schreger (2016) quantify the expected currency depreciation in emerging markets from the credit spread differential between sovereign bonds denominated in dollars and local currency.[4] Corradin and Rodriguez-Moreno (2014) and Buraschi et al. (2015) exploit quanto spreads to explain pricing anomalies between bond yields denominated in different currencies, while De Santis (2019) uses the quanto spread to analyze the risk of currency redenomination in the Eurozone.[5]

[3] The approach builds on Ehlers and Schoenbucher (2004), who use Japanese corporate CDS denominated in dollars and yen to analyze the expected exchange rate.

[4] The authors compute the credit risk components of sovereign yields in local and foreign currencies by creating an artificial local risk-free rate based on the US treasury bonds, US LIBOR rates, local LIBOR rates, and currency swaps.

[5] In a complement study, Kremens (2022) exploits the legal differences of sovereign CDS contracts for a given country (i.e., the ISDA basis) to understand currency redenomination risk for Eurozone member states.

This paper also complements two recent studies. Lando and Bang Nielsen (2018) show that quanto spreads reflect the risk that a currency depreciates not only at the time of default but also as default risk increases. Their contribution is to decompose theoretically and empirically these two effects. Augustin et al. (2020) use the term structure of quanto spreads to offer an asset-pricing perspective on the relationship between sovereign defaults and currency depreciation in the Eurozone and on the possibility of credit contagion. They address the debate on whether a default has an immediate or gradual impact on the exchange rate, thereby contributing to a better understanding of the "Twin Ds" (depreciation and default). Their findings provide strong support in favor of the first channel. They show that the currency risk premium associated with depreciation in default has an upward term structure (i.e., increases with the horizon), while we focus on the conditional properties of the currency risk premium at a given horizon to study exchange rate predictability. Taken together, these papers offer a comprehensive view on the asset pricing implications of the interaction between currency depreciation and default for the credit derivative and currency markets.

Overall, we contribute to the existing literature by identifying a credit-implied currency risk premium that has strong implications for exchange rate predictability. Since the path-breaking contribution of Meese and Rogoff (1983), a vast body of empirical studies finds that economically meaningful variables fail to empirically predict exchange rate returns. While there is some evidence that exchange rates and economic fundamentals move together over long horizons (Mark, 1995), the general view is that exchange rates are not predictable, especially at short horizons. The contribution of our paper is to report robust empirical evidence that the dollar-euro exchange rate is predictable at short horizons using a novel theoretically-motivated risk premium measure. Our findings confirm the view that a risk premium capturing investors' expectations about a currency depreciation upon default is informative about future exchange rate movements.

The remainder of the paper is organized as follows. Section 2 develops a theory that identifies the credit-implied currency risk premium, which we quantify using the price difference of dollar-denominated and euro-denominated CDS contracts. Section 3 describes the data and provides a descriptive analysis, whereas Section 4 provides empirical evidence of exchange rate predictability at various horizons. We discuss the economic value of such predictability in Section 5 before concluding in Section 6. The Internet Appendix contains technical details and presents additional results not included in the main body of the paper.

2. Theory

In this section, we extend the theory of Kremens and Martin (2019) and identify a novel component for exchange rate predictability. We focus on the dollar-euro exchange rate, but the theory can be applied to other currency pairs.

2.1. Environment

Consider a currency strategy that converts a dollar into euros, lends at the euro riskless rate for a period, and then exchanges the proceeds in euros for dollars next period. According to the fundamental equation of asset pricing, the expected gross exchange rate return is given by

$$\mathbb{E}_t\left[\frac{S_{t+1}}{S_t}\right] = \frac{R^{\$}_{f,t}}{R^{€}_{f,t}} - R^{\$}_{f,t} cov_t\left(M_{t+1}, \frac{S_{t+1}}{S_t}\right), \tag{1}$$

where $\mathbb{E}_t$ is the expectation operator (under the physical measure) conditional on the information available at time t, S_t is the dollar-euro (USD/EUR) spot exchange rate defined as units of dollars per euro such that an increase in S_t reflects a euro appreciation, $R^{\$}_{f,t}$ ($R^{€}_{f,t}$) is the one-period gross dollar (euro) interest rate, and M_{t+1} is a stochastic discount factor (SDF) that prices assets denominated in dollars.

Under the risk-neutral expectation $\mathbb{E}^*_t$, the covariance term disappears and the identity in Eq. (1) simplifies to the Uncovered Interest Parity (UIP) condition, which predicts a depreciation of the higher interest rate currency as

$$\mathbb{E}^*_t\left[\frac{S_{t+1}}{S_t}\right] = \frac{R^{\$}_{f,t}}{R^{€}_{f,t}}. \tag{2}$$

The UIP condition, however, fails empirically to predict future exchange rate returns and the resulting currency excess returns are generally interpreted as compensation for time-varying risk (e.g., Fama, 1984; Lustig et al., 2011). This is equivalent to saying that expected exchange rate returns depend not only on the interest rate differential but also on a risk adjustment component captured by the covariance between the SDF and the gross exchange rate return.

The challenging aspect in Eq. (1) is that the SDF is unobservable ex-ante and likely to change over time, thus not being helpful for exchange rate predictability. To overcome this problem, Kremens and Martin (2019) rewrite Eq. (1) in terms of the risk-neutral covariance between the exchange rate return and the dollar return of a diversified basket of stocks, which is a primary ingredient of their quanto-implied risk premium. We show below that a novel risk premium component, which we label the credit-implied risk premium, coexists with the quanto-implied risk premium.

2.2. Global portfolio

Consider an investor holding a global portfolio of dollar-denominated assets whose gross return X_{t+1} comprises two distinct risky components r_{t+1} and d_{t+1} such that

$$X_{t+1} = 1 + r_{t+1} + d_{t+1}. \tag{3}$$

The component r_{t+1} captures the return on a diversified basket of US stocks, like the S&P 500 index in Kremens and Martin (2019). We denote the *gross* return of this basket as $R_{t+1} = 1 + r_{t+1}$ such that $\mathbb{E}_t[M_{t+1}R_{t+1}] = 1$.

The component d_{t+1} is the excess return of an asset whose future value depends on the realization of a sovereign default in the Eurozone, a rare but severe event affecting the USD/EUR exchange rate. Specifically, let $\boldsymbol{D}$ be an indicator function that takes on the value of one (and zero otherwise) if a default occurs with risk-neutral probability $\mathbb{Q}_t$. An investor that buys this asset receives a constant compensation a but face a potential loss b in the case of default such that $d_{t+1} = a - \boldsymbol{D}b$.[6] For example, consider a one-period dollar-denominated bond issued by a Eurozone country which pays a yield spread a known at time t but embeds a potential loss b in the case of a default (the relative difference between the unrecovered bond value and its face value) at time $t+1$. Alternatively, our investor could sell a one-period (uncollateralized) CDS contract on this bond. She would receive a premium a but deliver a compensation b to the protection buyer if the reference bond is affected by a default event. Both cases, formally derived in Internet Appendix A, affect the global portfolio X_{t+1} negatively in the case of a sovereign default. Since d_{t+1} is the contingent asset's *excess* return, we have that $\mathbb{E}_t[M_{t+1}d_{t+1}] = 0$ and $\mathbb{E}_t[M_{t+1}X_{t+1}] = \mathbb{E}_t[M_{t+1}R_{t+1}] + \mathbb{E}_t[M_{t+1}d_{t+1}] = 1$.[7]

The global portfolio does not expose the investor to currency risk as both R_{t+1} and d_{t+1} are measured in dollars. However, the euro becomes risky for the investor if it covaries with the performance of the global portfolio, especially in the case of a sovereign default. In this case, the expected gross exchange rate return between t and $t+1$ is given by the following identity where the expected exchange rate return depends, beyond the interest rate differential and a residual term A_t, on two distinct risk adjustment terms:

$$\mathbb{E}_t\left[\frac{S_{t+1}}{S_t}\right] = \underbrace{\frac{R^{\$}_{f,t}}{R^{€}_{f,t}}}_{\text{UIP forecast}} + \underbrace{\frac{1}{R^{\$}_{f,t}} cov^*_t\left(\frac{S_{t+1}}{S_t}, R_{t+1}\right)}_{\text{Quanto-implied risk premium}} + \underbrace{\frac{1}{R^{\$}_{f,t}} cov^*_t\left(\frac{S_{t+1}}{S_t}, d_{t+1}\right)}_{\text{Credit-implied risk premium}} + A_t \quad (4)$$

While the residual component A_t is not directly observable as in Kremens and Martin (2019), we will proxy for it using a variety of control variables suggested by the recent literature, which we describe in Section 3.3.

The second term in Eq. (4) captures the conditional risk-neutral covariance between the gross exchange rate return and the gross US stock market return R_{t+1}. Kremens and Martin (2019) show that this component can be extracted from a quanto forward, i.e., a derivative settled in a currency that is different from the currency of the underlying instrument, and thus refer to it as the *quanto-implied risk premium* (QRP). The value of the quanto forward on the S&P 500 index settled in euro varies with the forward-looking covariance between the S&P 500 index and the USD/EUR exchange rate. If the euro is expected to depreciate against the dollar when the US stock market falls, then QRP is positive and investors demand a risk premium for holding euros.

The third term in Eq. (4) reflects the conditional risk-neutral covariance between the gross exchange rate return and the excess return of the dollar-denominated contingent asset d_{t+1}, which we label the *credit-implied risk premium* (CRP). This risk-neutral covariance, given by

$$cov^*_t\left(\frac{S_{t+1}}{S_t}, d_{t+1}\right) = \mathbb{Q}_t b\left(\mathbb{E}^*_t\left[\frac{S_t - S_{t+1}}{S_t}\,\Big|_{\boldsymbol{D}=1}\right] - \mathbb{E}^*_t\left[\frac{S_t - S_{t+1}}{S_t}\right]\right), \quad (5)$$

captures the difference between the risk-neutral expected euro depreciation conditional on a sovereign default, defined as $\mathbb{E}^*_t[(S_t - S_{t+1})/S_t|_{\boldsymbol{D}=1}]$, and the risk-neutral expected euro depreciation implied from the UIP condition given by $\mathbb{E}^*_t[(S_t - S_{t+1})/S_t]$ (see the Internet Appendix B). If the euro is expected to depreciate against the dollar in the case of a sovereign default in the Eurozone, in excess of what is predicted by UIP, then the credit-implied risk premium is positive and investors demand an additional risk premium for holding euros.[8]

Our extension of Kremens and Martin (2019)'s framework highlights the presence of two separate and complementary sources of risk premia in currency markets. While QRP arises from small but frequent shocks affecting US stocks, the credit-implied risk premium captures the euro depreciation during a rare but severe shock in the Eurozone that does not necessarily impact the investor's stock holdings. For example, the sovereign default of Greece in 2012 caused large losses to government bondholders and CDS protection sellers without having a significant effect on the US stock market.[9] Both components thus capture distinct information.

The next section shows that the risk-neutral expected depreciation upon default, a key ingredient of the credit-implied risk premium, can be constructed using differences in sovereign CDS premia of the same reference entity but quoted in different currencies. This difference is commonly called the quanto CDS by market participants (see, for example, Elizalde et al., 2010).

2.3. Expected depreciation conditional on default

A sovereign CDS is a credit derivative that offers protection against a sovereign credit event.[10] For this protection, the buyer pays a periodic annualized CDS premium

[6] The contingent asset can be a bond, derivative, or a structured product whose payoff depends on the occurrence of any uncertain future event, such as a recession, natural disaster, war, or a political crisis.

[7] As a simple numerical example, suppose r_{t+1} is 10%, a is 5%, and b is 40%. In absence of default, $\boldsymbol{D} = 0$, $R_{t+1} = 1.1$, $d_{t+1} = 0.05$, and $X_{t+1} = 1.15$. In the case of a default, $\boldsymbol{D} = 1$, $R_{t+1} = 1.1$, $d_{t+1} = -0.35$, and $X_{t+1} = 0.75$.

[8] This risk premium vanishes if the exchange rate is independent of the event, the corresponding probability is nil ($\mathbb{Q}_t$), or if the portfolio has no exposure to the event ($b = 0$), thus nesting the setting of Kremens and Martin (2019).

[9] Similarly, the majority of sovereign defaults affecting emerging economies (e.g., Russia in 1999, Argentina in 2001, Indonesia in 2002, Venezuela in 2005, or Ukraine in 2015) had a very limited impact on the US stock market. As an extension of our core empirical analysis on the Eurozone, we also investigate in Section 4.4 the predictability of the credit-implied risk premium for emerging market currencies.

[10] The ISDA identifies four main types of credit or default events, namely, obligation acceleration, failure to pay the interest or principal, restructuring of debt, and repudiation or moratorium of debt (e.g., ISDA, 2003).

to the seller, which is quoted as a percentage of the notional value specified at the inception date. The seller, in turn, compensates the holder with a contingent payment related to the unrecovered value of the underlying bond in the case of a defined credit event. Sovereign CDS contracts on the same reference entity can be denominated in different currencies. While dollar-denominated CDS contracts are widely traded, local-currency denominated instruments are frequently used for asset-liability and risk management purposes. For example, European banks and investment funds largely use euro-denominated sovereign CDS written on Eurozone member states to offset a credit valuation adjustment.

In contrast to a dollar-denominated CDS, a euro-denominated CDS exposes a US protection buyer to currency risk as the euro is expected to depreciate against the dollar in a default event, precisely when the protection buyer receives the payoff from the protection seller. An investor would then pay a higher premium on a dollar-denominated CDS than on a euro-denominated contract although these instruments are otherwise identical. Fig. 1 plots one-year dollar-denominated and euro-denominated CDS premia for selected Eurozone member states and confirms the relatively higher price for dollar-denominated instruments, especially during the European sovereign debt crisis.

We now exploit the price differences between CDS denominated in different currencies. Specifically, we show that the risk-neutral expected currency depreciation conditional on a sovereign default in Eq. (5) can be synthesized from an arbitrage-free strategy implemented with euro-denominated and dollar-denominated CDS contracts written on the same reference entity. To ease the exposition, we present a one-period strategy that starts at time t and ends at time $t+1$ with a potential default event that occurs at time $t+1$ as summarized by Fig. 2. A more general setting is discussed in the Internet Appendix C.

Let $C_t^{€}$ and $C_t^{\$}$ be the euro-denominated and dollar-denominated CDS premia on the same sovereign debt at time t, respectively, with corresponding notional values $N^{€}$ and $N^{\$}$. We consider a US investor who offsets sovereign risk by going long the euro-denominated CDS and short the dollar-denominated CDS. On this long-short strategy, the investor will pay a premium of $C_t^{€} N^{€}$ on the long position and receive a premium of $C_t^{\$} N^{\$}$ on the short position while hedging the currency risk associated with the euro-denominated premium via a fixed-for-fixed currency swap that delivers dollars for euros at a given swap rate. The latter is set equal to S_t, namely, the spot exchange rate observed at the inception date of the strategy, as in Du and Schreger (2016). The recovery rate of the underlying sovereign bond is $R_r \in (0,1)$ such that the CDS protection buyer receives the fraction of the unrecovered bond value $(1-R_r)$ times the exposure of the CDS contract.

The cash flow CF_t on our arbitrage-free strategy at the inception date t is given by

$$CF_t = C_t^{\$} N^{\$} - C_t^{€} N^{€} S_t, \tag{6}$$

which implies that $N^{\$} = C_t^{€} N^{€} S_t / C_t^{\$}$ for a self-financing strategy with $CF_t = 0$. At default, the investor receives $(1-R_r)N^{€}$ from the euro-denominated CDS converted in dollars at the spot exchange rate S_{t+1} and delivers $(1-R_r)N^{\$}$ on the dollar-denominated CDS. In the absence of arbitrage, the risk-neutral expectation of the future cash flow conditional on default must then satisfy the following condition

$$\mathbb{E}_t^*[CF_{t+1}|_{\boldsymbol{D}=1}] = (1-R_r)N^{€}\, \mathbb{E}_t^*[S_{t+1}|_{\boldsymbol{D}=1}] - (1-R_r)N^{\$} = 0. \tag{7}$$

It then follows, by combining Eqs. (6) and (7), that the risk-neutral expectation at time t of the euro depreciation conditional on default corresponds to the relative CDS premium difference:

$$\mathbb{E}_t^*\left[\frac{S_t - S_{t+1}}{S_t}\,\Big|_{\boldsymbol{D}=1}\right] = \frac{C_t^{\$} - C_t^{€}}{C_t^{\$}}. \tag{8}$$

The arbitrage-free strategy underlying the closed-form solution in Eq. (8) assumes for simplicity that the default event can only occur at time $t+1$. Such a default, however, may also happen between times t and $t+1$. In this case, we should account for the accrued CDS premium, i.e., the residual part of the CDS premium paid (received) by the protection buyer (seller), and the residual value of the currency swap. Also, an investor could trade multi-period CDS contracts as opposed to one-period contracts. We consider these additional aspects in the Internet Appendix C.[11]

3. Data and preliminary analysis

In this section, we describe the sovereign CDS data and the computation of the credit-implied risk premium for the Eurozone. We then present a descriptive analysis and introduce the remaining variables we consider in the paper.

3.1. Sovereign CDS data

Our analysis uses mid-quotes on dollar-denominated and euro-denominated sovereign CDS premia with the complete restructuring clause from IHS Markit. Although dollar-denominated sovereign CDS are the most traded contracts, euro-denominated sovereign CDS are also fairly liquid for the Eurozone member states (Augustin et al., 2020). We collect daily observations for 16 countries, which are Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, the Netherlands, Portugal, Slovenia, Slovakia, and Spain from August 2010 to April 2019. We exclude Greece because of infrequent quotes. In addition, we focus on one-year CDS premia, because short-maturity CDS contracts tend to be particularly informative about sovereign default risk compared to longer-maturity ones (Augustin, 2018).

[11] In the general setting, the residual value of the currency swap depends on the remaining time to maturity in the case of a default. We can determine the cash flow for each possible default time and weigh it with the corresponding risk-neutral default probability extracted from the term structure of CDS premia. Closed-form solutions for the implied currency depreciation do no longer exist and we must rely on an iterative procedure. Using one-period maturity CDS contracts helps to conveniently overcome this issue.

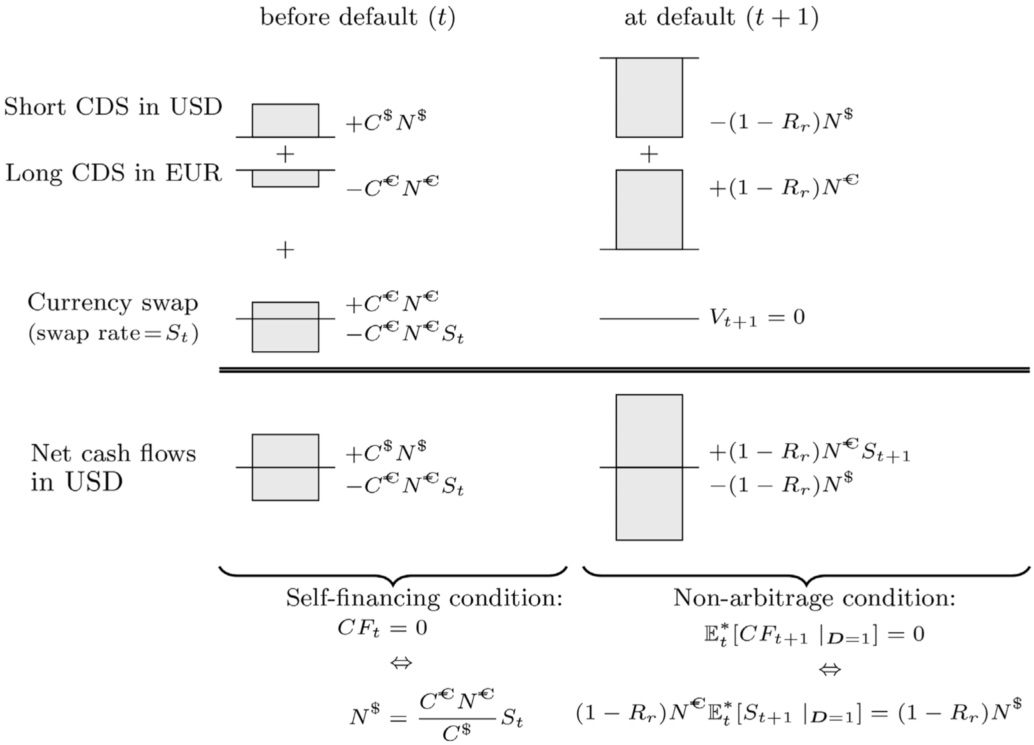

Fig. 2. Cash flows of a long-short CDS strategy. *Note:* This figure displays the cash flows of a strategy that simultaneously goes long a euro-denominated and short a dollar-denominated sovereign CDS written on the same underlying entity while hedging the exchange rate via a currency swap. The strategy starts at time t and ends at time $t+1$ with a potential default event at time $t+1$. This long-short strategy is discussed in Section 2.3.

3.2. Credit-implied risk premium

We construct the credit-implied risk premium presented in Eqs. (4) and (5) by first computing its empirical counterpart for each Eurozone country i as follows

$$CRP_{i,t} = \frac{b\overline{\mathbb{Q}}_i}{R^{\$}_{f,t}}\left(\underbrace{\frac{C^{\$}_{i,t}-C^{€}_{i,t}}{C^{\$}_{i,t}}}_{ICD_{i,t}} - \underbrace{\frac{R^{€}_{f,t}-R^{\$}_{f,t}}{R^{€}_{f,t}}}_{ECD_t}\right), \tag{9}$$

where $C^{\$}_{i,t}$ ($C^{€}_{i,t}$) is the one-year dollar-denominated (euro-denominated) CDS premium, $R^{\$}_{f,t}$ ($R^{€}_{f,t}$) is the one-year dollar (euro) gross interest rate, and b is the loss given default set equal to 0.6 following the ISDA convention. The first component in parentheses denotes the risk-neutral expected euro depreciation upon default, labeled the *implied currency depreciation* ($ICD_{i,t}$), which varies across countries. The second term is the risk-neutral expected euro depreciation predicted by the UIP condition (ECD_t) and is common across all countries.

In Eq. (9), $\overline{\mathbb{Q}}_i$ denotes the constant risk-neutral probability of default extracted from one-year dollar-denominated CDS premia.[12] Since our main objective is to study the role of expected currency depreciation upon sovereign default for exchange rate predictability, we work with time-invariant $\overline{\mathbb{Q}}_i$ as opposed to time-variant $\mathbb{Q}_{i,t}$ throughout our core analysis. In doing so, we avoid that the credit-implied risk premium is contaminated with time-variation in distress risk premia and potential noise related to global financial conditions, which contain no predictive ability for exchange rate returns.[13] The risk-neutral probability of default plays, however, a critical role in the cross-section, as the credit-implied risk premium should be larger for countries with higher default risk.

The country-specific quantities in Eq. (9) are then combined using a cross-country weighted average

$$CRP_t = \sum_i \omega_i CRP_{i,t}, \tag{10}$$

where ω_i reflects the relative size of country i's sovereign debt such that a country with a larger outstanding debt naturally contributes more to the credit-implied risk premium. As an alternative weighting scheme, we employ the relative size of each country i's gross domestic product (GDP). In both cases, the weights are calculated at the beginning of our sample (using data collected from Bloomberg and Eurostat) and then kept fixed until the end of the sample such that any time-series variation should

[12] Estimates of $\overline{\mathbb{Q}}_i$ are based on the full sample of dollar-denominated CDS premia for the in-sample exercise but only on the first year of data for the out-of-sample analysis. For additional computational details, see the Internet Appendix C.4.

[13] We examine the time variation of the risk-neutral default probability, its relation with global financial conditions, and its (lack of) predictive ability for the USD/EUR exchange rate returns in Section 4.3 and in the Internet Appendix G.

Table 1
Descriptive statistics.
This table describes the credit-implied risk premium and its underlying components in percentage per annum. Panel A displays, for each Eurozone country, descriptive statistics for the credit-implied risk premium ($CRP_{i,t}$) and the implied currency depreciation upon default ($ICD_{i,t}$) based on the difference between dollar-denominated and euro-denominated one-year CDS premia. $\overline{\mathbb{Q}}_i$ is the risk-neutral probability of default extracted from dollar-denominated one-year CDS (full-sample) and ω_i is the weight of country i based on its level of sovereign debt or GDP for the year 2010. Panel B shows descriptive statistics for the debt-weighted and GDP-weighted CRP_t and ICD_t for the Eurozone. P_5 (P_{95}) denotes the 5th (95th) percentile. The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg and IHS Markit.

Panel A: Country variables

	$CRP_{i,t}$ (%)				$ICD_{i,t}$ (%)				$\overline{\mathbb{Q}}_i$ (%)	ω_i (%)	
	mean	std	P_5	P_{95}	mean	std	P_5	P_{95}		Debt	GDP
Austria	0.06	0.02	0.02	0.09	31.30	11.45	10.44	50.45	0.32	3.2	3.2
Belgium	0.08	0.05	−0.01	0.17	22.60	13.87	−1.81	45.80	0.61	4.7	3.9
Cyprus	0.27	0.44	−0.39	1.07	5.25	9.60	−8.34	24.31	7.78	0.1	0.2
Estonia	0.02	0.03	−0.02	0.08	8.09	11.36	−7.43	28.31	0.46	0.0	0.2
Finland	0.02	0.01	0.00	0.04	23.09	13.81	1.21	44.02	0.17	1.1	2.0
France	0.06	0.03	0.01	0.10	27.58	13.42	3.12	47.32	0.35	21.2	21.5
Germany	0.03	0.02	0.00	0.05	29.92	17.96	−2.26	57.75	0.14	27.2	27.8
Ireland	0.31	0.17	0.04	0.57	17.54	9.10	3.87	31.83	2.85	1.9	1.8
Italy	0.19	0.09	0.07	0.33	18.80	8.41	6.64	31.81	1.69	24.1	17.3
Latvia	0.03	0.07	−0.09	0.10	4.95	12.17	−15.82	18.49	0.94	0.1	0.2
Lithuania	0.04	0.05	−0.04	0.11	7.68	9.30	−6.86	20.94	0.92	0.1	0.3
Netherlands	0.04	0.02	0.01	0.07	30.50	13.04	4.54	50.88	0.22	4.9	6.9
Portugal	0.37	0.19	0.08	0.68	12.59	6.10	3.35	22.72	4.70	2.3	1.9
Slovakia	0.04	0.04	−0.01	0.11	11.33	11.78	−3.69	34.60	0.58	0.4	0.7
Slovenia	0.08	0.08	−0.02	0.26	10.97	11.35	−1.88	36.27	1.22	0.2	0.4
Spain	0.20	0.07	0.10	0.31	20.21	6.99	10.03	31.11	1.63	8.5	11.6

Panel B: Eurozone variables

	CRP_t (%)				ICD_t (%)						
	mean	std	P_5	P_{95}	mean	std	P_5	P_{95}			
Debt-weighted	0.11	0.03	0.05	0.15	24.70	7.65	9.83	36.05	–	–	–
GDP-weighted	0.10	0.03	0.05	0.14	25.00	7.70	10.38	36.76	–	–	–

be solely attributed to changes in country-specific credit-implied risk premia. For robustness, we also consider an equally-weighted credit-implied risk premium measure. The Internet Appendix D provides additional details on the construction of CRP_t.

We report descriptive statistics for the credit-implied risk premium and its underlying components in percentage per annum in Table 1. In Panel A, we present country-specific descriptive statistics for the credit-implied risk premium ($CRP_{i,t}$) and the implied currency depreciation upon default ($ICD_{i,t}$) based on the difference between one-year dollar-denominated and euro-denominated CDS premia. We also report, for each Eurozone country, the risk-neutral probability of default ($\overline{\mathbb{Q}}_i$) extracted from the full-sample of one-year dollar-denominated CDS premia and the weights (ω_i) constructed using public debt or GDP data for the year 2010. We find that the safest and economically most important countries exhibit, on average, the highest implied currency depreciation upon default. The mean value of $ICD_{i,t}$, for example, ranges between 27.6% and 30.5% per annum for France, Germany, and the Netherlands. The level of creditworthiness as measured by $\overline{\mathbb{Q}}_i$ is also highly heterogeneous among Eurozone countries: high for Cyprus, Portugal, Ireland, Italy, and Spain (ranging between 7.78% and 1.63% per annum) and low for Germany, France, and the Netherlands (ranging between 0.35% and 0.14% per annum). Taken together, Portugal, Ireland, Cyprus, Spain, and Italy have, on average, the highest credit-implied risk premia. In contrast, countries playing a negligible financial role in the Eurozone (e.g., Estonia, Finland, and Latvia) or with high creditworthiness (e.g., Germany, France, and the Netherlands) have the lowest credit-implied risk premium.

In Panel B, we present descriptive statistics for the credit-implied risk premium for the Eurozone based on two different static weighting schemes. The debt-weighted (GDP-weighted) credit-implied risk premium amounts to 0.11% (0.10%) per annum.[14] The small magnitude of this risk premium, which is due to a low risk-neutral probability of default for large Eurozone countries, is consistent with the findings of Augustin et al. (2020), based on an affine non-arbitrage model. While being small on average, the credit-implied risk premium varies substantially over time as illustrated by Fig. 3, which plots the USD/EUR exchange rate in the top panel and the credit-implied risk premia (debt-weighted and GDP-weighted) in the bottom

[14] The difference in credit-implied risk premium with and without the accrued premium is negligible (approximately 0.001%) and the sample correlation between the two versions is above 99%. We thus ignore the accrued premium throughout the paper.

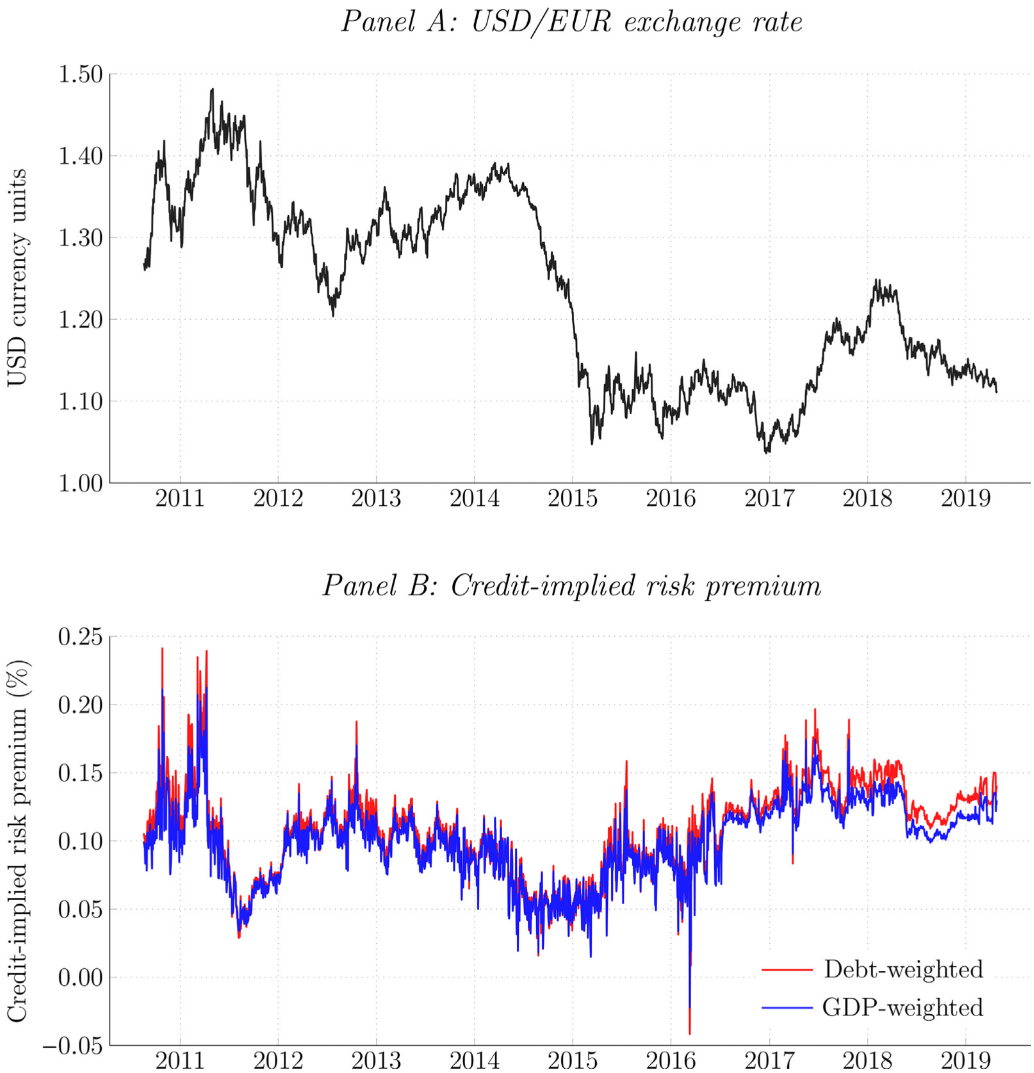

Fig. 3. Credit-implied risk premium for the Eurozone. *Note:* This figure plots the USD/EUR exchange rate (Panel A) and the credit-implied risk premium (CRP) for the Eurozone (Panel B). The exchange rate is defined as units of dollars per euro. CRP is constructed using country-level dollar-denominated and euro-denominated CDS premia weighted by sovereign debt or GDP. The countries included in the computation are Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, the Netherlands, Portugal, Slovenia, Slovakia, and Spain. The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg and IHS Markit.

panel. Visually, this figure reveals a positive predictive correlation between the credit-implied risk premium and future exchange rate returns. We will quantitatively assess this predictive relationship, both statistically and economically, in the next sections.

3.3. Other data

In the previous section, we have presented our recipe to construct the credit-implied risk premium. Below, we summarize the additional components we utilize in our empirical analysis.

Exchange rates. We collect the USD/EUR spot exchange rate from Bloomberg and express it in units of dollars per unit of euro such that an increase denotes a euro appreciation. In the robustness analysis, we employ other currency pairs from the same source with the first (second) currency being the quote (base) currency.

Interest rates. The first term in Eq. (4) is the traditional UIP forecast that we approximate with the one-year interest rate differential between the US and the Eurozone to match the maturity of the CDS contracts. For the construction of this component, we rely on daily zero-coupon rates bootstrapped from money market rates and interest rate swaps obtained from Bloomberg. We use the same source/methodology for other currency pairs in the robustness section.

Quanto-implied risk premium. The second component in Eq. (4) is the quanto-implied risk premium, which Kremens and Martin (2019) construct with euro-denominated two-year quanto forwards on the S&P 500 index available monthly until October 2015 from IHS

Markit.[15] In the next section, we will discuss several approaches to retrieve daily observations and extend the sample beyond October 2015.

Control variables. The identity presented in Eq. (4) holds up to a residual term, which we do not directly observe. We attempt to account for this missing term by augmenting our predictive regressions with additional variables that are known to empirically matter for exchange rate returns. Recent empirical evidence suggests that both liquidity and volatility play an important role in currency markets (e.g., Menkhoff et al., 2012; Karnaukh et al., 2015), and we thus employ an updated version of their measure of global FX illiquidity and volatility. The former is based on the bid-ask spreads of the spot exchange rate and is available from the authors' website, whereas we construct the latter using average absolute exchange rate returns for a cross-section of the 20 most liquid currency pairs.[16] Recent literature also highlights the role of portfolio-based currency factors such as carry, dollar, global imbalance, momentum, risk-reversal, and value (e.g., Lustig et al., 2011; Della Corte et al., 2016a; 2016b). While these factors are generally available at the monthly frequency, we retrieve daily observations by tracking the intra-month exchange rate returns on the underlying long and short baskets. Since the time-series variation of these factors only depends on exchange rate changes, we ignore the daily forward premium adjustment and focus purely on the exchange rate return component. Specifically, we first group currencies into five portfolios at the end of each month t using a pre-defined sorting criterion and then record the daily average exchange rate return of long-short baskets. We construct our factors using the 20 most liquid currency pairs.

Positions on currency futures. We employ, for the euro relative to the dollar, aggregate holdings of participants in the US currency futures markets from the Commitments of Traders (COT) Reports. Data are typically released every Friday by the Commodity Futures Trading Commission (CFTC) and reflect the commitments of traders for the prior Tuesday. We use position data from the legacy report, which provides a breakdown between commercial traders (using futures primarily to hedge their business activities) and non-commercial traders (using futures presumably for speculative and non-speculative positions). From the CFTC's website, we collect data for non-commercial traders and then construct their net demand (or speculative positions) for currency futures by taking the difference between long and short positions scaled by the total open interest. We use this time series to explore whether our out-of-sample forecasts based on the credit-implied risk premium relate to currency traders' expectations.

[15] A quanto forward on the S&P 500 index is a forward contract settled in euro and its value is sensitive to the correlation between the S&P 500 index and the dollar-euro exchange rate. If the euro appreciates (depreciates) against the dollar when the index is high (low), then QRP is positive.

[16] This sample includes the currencies of Australia, Brazil, Canada, Czech Republic, Denmark, Eurozone, Hungary, Japan, Mexico, New Zealand, Norway, Poland, Singapore, South Africa, South Korea, Sweden, Switzerland, Taiwan, Turkey, and United Kingdom.

4. Exchange rate predictability

In this section, we empirically test our theory by examining the exchange rate predictive ability of the credit-implied risk premium.

4.1. Baseline specification

We evaluate the predictive information content of the credit-implied risk premium by running regressions at the daily frequency based on the following specification:

$$\Delta_\kappa s_{t+\kappa} = \alpha_\kappa + \beta_\kappa IRD_t + \gamma_\kappa CRP_t + \phi_\kappa X_t + \varepsilon_{t+\kappa}, \quad (11)$$

where s_t is the log of the nominal USD/EUR exchange rate on day t, $\Delta_\kappa s_{t+\kappa} = s_{t+\kappa} - s_t$ is the exchange rate return between days t and $t+\kappa$, CRP_t is the credit-implied risk premium for the Eurozone based on country-level dollar-denominated and euro-denominated one-year CDS premia observed on day t, IRD_t is the one-year interest rate differential between the US and Eurozone observed on day t, X_t comprises a set of control variables observed on day t, and κ is the forecast horizon. To ease the comparison across different horizons, we convert all exchange rate returns in annual terms, i.e., we multiply the dependent variable in Eq. (11) by the constant term $252/\kappa$. We report the least squares estimates of γ_κ with and without control variables in Table 2 using the full sample period, which ranges between August 2010 and April 2019. Since the quanto-implied risk premium is not available for the full-sample and at the daily frequency, we do not include it in our baseline specification, but examine its role in the next section. We report estimates of γ_κ for different forecast horizons κ ranging between one week (five business days) and one year (252 business days).

Extending the forecast horizon beyond the sampling interval ($\kappa > 1$) may induce higher-order serial correlation, at least of order $\kappa - 1$, in the residuals $\varepsilon_{t+\kappa}$. We deal with this issue in two different ways. First, we calculate p-values based on Hansen and Hodrick (1980) standard errors with a lag truncation equal to κ and report them in parentheses.[17] Second, we construct confidence intervals via the stationary bootstrap of Politis and Romano (1994) and report estimates of γ_κ in bold when we detect statistical significance at 5% (or lower). The exercise consists of 1,000 replications in which blocks with a random length of dependent and independent variable realizations are simulated with replacement from the original sample without imposing any restrictions. More details are reported in the Internet Appendix F.1.

Consistent with our theory, Table 2 reports positive and statistically significant estimates of γ_κ, thus implying that CRP_t positively predicts future USD/EUR exchange rate returns. Estimates of α_κ, moreover, are always statistically indistinguishable from zero and remain unreported to save space. Panel A focuses on the benchmark specifications without the control variables in X_t and displays estimates

[17] The estimator of the variance-covariance matrix in Hansen and Hodrick (1980) is not guaranteed to be positive semi-definite. When it is not, we report p-values based on Newey and West (1987) standard errors with a lag truncation equal to κ (see, for example, Ang and Bekaert, 2007).

Table 2
FX predictability and credit-implied risk premium.
This table presents results on the exchange rate predictive ability of the credit-implied risk premium (CRP). The dependent variable is the daily average USD/EUR exchange rate return measured on a forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debt. Panel A presents the benchmark specification, which controls for the one-year interest rate differential between the US and Eurozone. Panel B (Panel C) adds global FX illiquidity and volatility (currency factors), whereas Panel D adds all control variables to the benchmark specification. We report p-values based on Hansen and Hodrick (1980) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using confidence intervals based on 1,000 stationary bootstrap repetitions (Politis and Romano, 1994). The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

	Panel A: Benchmark specification					Panel B: Adding liquidity and volatility				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.229****	**2.407****	**2.155*****	**1.852****	**1.009****	**2.272****	**2.447****	**2.181*****	**1.879*****	**1.039*****
	(0.023)	(0.016)	(0.004)	(0.013)	(0.034)	(0.021)	(0.014)	(0.002)	(0.000)	(0.001)
R^2 (%)	1.08	6.24	16.26	23.35	20.26	1.13	6.68	18.24	34.00	42.54
N	2,154	2,138	2,096	2,033	1,907	2,154	2,138	2,096	2,033	1,907
	Panel C: Adding currency factors					Panel D: Adding all controls				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.267****	**2.432****	**2.168*****	**1.858****	**1.017****	**2.314****	**2.472****	**2.194*****	**1.886*****	**1.045*****
	(0.022)	(0.015)	(0.001)	(0.006)	(0.038)	(0.019)	(0.013)	(0.001)	(0.000)	(0.001)
R^2 (%)	1.25	6.12	16.21	23.24	20.13	1.32	6.57	18.24	33.96	42.56
N	2,154	2,138	2,096	2,033	1,907	2,154	2,138	2,096	2,033	1,907

of γ_κ ranging between 2.229 (with a p-value of 0.023) at the one-week horizon and 1.009 (with a p-value of 0.034) at the one-year horizon. The statistical evidence is further confirmed by our bootstrap exercise as all estimates of γ_κ are reported in bold. Panel B adds global FX illiquidity and FX volatility (e.g., Menkhoff et al., 2012; Karnaukh et al., 2015) as control variables and reports qualitatively similar results. Panel C adds a variety of portfolio-based currency factors such as the dollar, carry, momentum, value, external imbalances, and option risk reversals (e.g., Lustig et al., 2011) as control variables and continues to find statistically significant estimates of γ_κ at any horizon κ. Panel D, finally, considers all control variables and CRP_t remains a strong predictor of future exchange rate returns. The estimates of γ_κ range between 2.314 (significant at the 5% level) at the one-week horizon and 1.045 (significant at the 1% level) at the one-year horizon.[18] In economic terms, a coefficient estimate of 2.472 at the one-month horizon suggests that a one standard deviation increase in CRP_t predicts a future appreciation of the euro of about 7.9% per annum.

In our core exercise, the credit-implied risk premium for the Eurozone weighs a country's credit-implied risk premium by its level of outstanding sovereign debt. We repeat our predictability analysis using a different weighting scheme, i.e., we build the credit-implied risk premium for the Eurozone by weighting a country's credit-implied risk premium by its GDP, also measured at the beginning of our sample. We report the results in Table 3 and obtain qualitatively identical results. Predictability also holds with an equally-weighted credit-implied risk premium measure (see Table A.3 in the Internet Appendix).[19] Overall, our analysis indicates that the credit-implied risk premium positively predicts future USD/EUR exchange rate returns. The effect is both statistically and economically important and is not spanned by existing exchange rate return predictors.

4.2. Controlling for the quanto-implied risk premium

We now augment the baseline specification presented in Eq. (11) and evaluate the predictive ability of the credit-implied risk premium based on the following specification:

$$\Delta_\kappa s_{t+\kappa} = \alpha_\kappa + \beta_\kappa IRD_t + \gamma_\kappa CRP_t + \delta_\kappa QRP_t + \phi_\kappa X_t + \varepsilon_{t+\kappa}, \quad (12)$$

where QRP_t is the quanto-implied risk premium of Kremens and Martin (2019) based on euro-denominated quanto forwards on the S&P 500 index. Recall that this predictor is only available at the monthly frequency and until October 2015. To fill this gap, we run additional predictive regressions using alternative methods (described below) to proxy for the daily quanto-implied risk premium over the full sample. We report the least-squares estimates of γ_κ in Table 4.

In Panel A, we retrieve daily missing observations on the quanto-implied risk premium between August 2010 and November 2015 by forward-filling, i.e., we keep the latest available observation constant until a new observation becomes available. Empirically, our credit-implied risk

[18] We also employ both Newey and West (1987) standard errors with a lag truncation equal to κ and Newey and West (1987) standard errors with Andrews (1991) optimal lag length and obtain comparable results. The evidence is reported in Table A.2 in the Internet Appendix.

[19] Statistical significance, however, tends to weaken because smaller countries have now larger weights. This result is consistent with the view that a default affecting a larger and economically more important Eurozone country should have a stronger impact on the USD/EUR exchange rate. See the Internet Appendix J.2 for a country-level analysis.

Table 3
FX predictability and credit-implied risk premium: GDP-weighted.
This table presents results on the exchange rate predictive ability of the credit-implied risk premium (CRP). The dependent variable is the daily average USD/EUR exchange rate return measured on a forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by GDP. Panel A presents the benchmark specification, which controls for the one-year interest rate differential between the US and Eurozone. Panel B (Panel C) adds global FX illiquidity and volatility (currency factors), whereas Panel D adds all control variables to the benchmark specification. We report p-values based on Hansen and Hodrick (1980) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using confidence intervals based on 1,000 stationary bootstrap repetitions (Politis and Romano, 1994). The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

Panel A: Benchmark specification						*Panel B: Adding liquidity and volatility*				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.562****	**2.717****	**2.484*****	**2.158*****	**1.176****	**2.626****	**2.774****	**2.522*****	**2.194*****	**1.218*****
	(0.020)	(0.013)	(0.003)	(0.008)	(0.015)	(0.018)	(0.011)	(0.001)	(0.000)	(0.000)
R^2 (%)	1.12	6.21	16.82	24.56	20.86	1.18	6.69	18.89	35.29	43.32
N	2,154	2,138	2,096	2,033	1,907	2,154	2,138	2,096	2,033	1,907
Panel C: Adding currency factors						*Panel D: Adding all control variables*				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.601****	**2.744****	**2.498*****	**2.166*****	**1.185****	**2.669****	**2.802*****	**2.537*****	**2.202*****	**1.225*****
	(0.020)	(0.013)	(0.003)	(0.008)	(0.015)	(0.017)	(0.010)	(0.000)	(0.000)	(0.000)
R^2 (%)	1.29	6.09	16.78	24.46	20.73	1.37	6.58	18.89	35.25	43.34
N	2,154	2,138	2,096	2,033	1,907	2,154	2,138	2,096	2,033	1,907

Table 4
Controlling for the quanto-implied risk premium.
This table presents results on the exchange rate predictive ability of the credit-implied risk premium (CRP) accounting for the quanto-implied risk premium (QRP) of Kremens and Martin (2019). The dependent variable is the daily average USD/EUR exchange rate return measured on a forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debt. In Panel A, QRP uses monthly euro-denominated quanto forwards on the S&P 500 index (retrieved daily by forward filling) available until October 2015. In Panel B, daily missing observations are recovered by combining risk-neutral volatility and correlation components, i.e., one-year VIX index, one-year model-free USD/EUR option implied volatility akin to Britten-Jones and Neuberger (2000), and risk-neutral correlation inferred monthly (and kept constant intra-month) from the quanto forwards. The latter is replaced after October 2015 with the one-year realized return correlation between the S&P 500 index and the USD/EUR exchange rate. In Panels C and D, QRP is synthetically replicated using the USD/EUR one-year option implied variance based, respectively, on the model-free (MF) approach of Britten-Jones and Neuberger (2000) and the simple (SI) variance method of Martin (2017). All specifications control for the one-year interest rate differential between the US and Eurozone, global FX liquidity, volatility, and currency factors. We report p-values based on Hansen and Hodrick (1980) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using confidence intervals based on 1,000 stationary bootstrap repetitions (Politis and Romano, 1994). The sample consists of daily observations between August 2010 and November 2015 (April 2019) in Panel A (Panels B–D). Data are from Bloomberg, Datastream, and IHS Markit.

Panel A: Controlling for monthly QRP						*Panel B: Controlling for daily QRP*				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.150***	**2.625****	**2.561*****	**2.350*****	**0.948*****	**2.265****	**2.530*****	**2.195*****	**1.706*****	0.662***
	(0.088)	(0.011)	(0.000)	(0.000)	(0.000)	(0.025)	(0.008)	(0.000)	(0.001)	(0.007)
R^2 (%)	1.95	9.93	32.35	64.93	81.35	1.28	6.54	18.20	34.69	47.25
N	1,313	1,297	1,255	1,192	1,066	2,154	2,138	2,096	2,033	1,907
Panel C: Controlling for daily synthetic QRP_{MF}						*Panel D: Controlling for daily synthetic QRP_{SI}*				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.329****	**2.500****	**2.157*****	**1.875*****	**0.979*****	**2.281****	**2.471****	**2.140*****	**1.862*****	**0.974*****
	(0.019)	(0.008)	(0.000)	(0.000)	(0.002)	(0.022)	(0.008)	(0.000)	(0.000)	(0.002)
R^2 (%)	1.28	6.53	18.25	33.93	42.92	1.28	6.52	18.29	33.95	42.90
N	2,154	2,138	2,096	2,033	1,907	2,154	2,138	2,096	2,033	1,907

premium continues to predict the USD/EUR exchange rate return for any horizon κ.

The forward-filling procedure, despite being common in empirical work for its simplicity, may underestimate the information content of the quanto-implied risk premium and introduce a bias in the estimation. To overcome this legitimate concern, we can retrieve daily missing observations on the quanto-implied risk premium in Eq. (4) by relying on a simple decomposition that involves risk-neutral volatility and correlation components, i.e., $cov_t^*(S_{t+1}/S_t, R_{t+1}) = \sqrt{var_t^*(S_{t+1}/S_t)}\sqrt{var_t^*(R_{t+1})}\,cor_t^*(S_{t+1}/S_t, R_{t+1})$.[20] In our calculations, we measure the daily risk-neutral return volatilities using the

[20] We are grateful to Lukas Kremens for suggesting this approach.

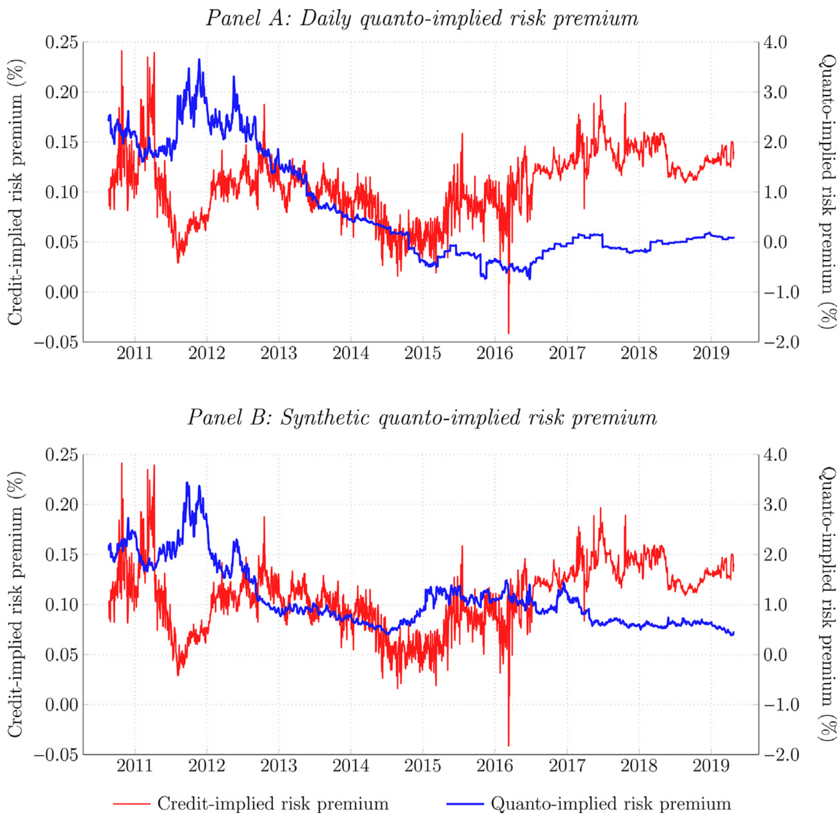

Fig. 4. Quanto-implied risk premium for the Eurozone. *Note:* Panel A displays the debt-weighted credit implied risk-premium and the daily version of the quanto-implied risk premium of Kremens and Martin (2019) recovered by combining daily risk-neutral volatilities and correlation, i.e., one-year VIX index, one-year model-free USD/EUR option implied volatility, and the risk-neutral correlation inferred monthly (and kept constant intra-month) from quanto forwards on the S&P 500 index. The latter is replaced after October 2015 with the one-year realized return correlation between the S&P 500 index and the USD/EUR exchange rate. Panel B plots the debt-weighted credit implied risk-premium and the daily synthetic quanto-implied risk premium based on the one-year model-free USD/EUR option implied variance, assuming that the investor holds a euro-denominated riskless bond rather than a diversified portfolio of stocks. The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg and IHS Markit.

one-year USD/EUR option implied volatility and the one-year VIX index, respectively, whereas the construction of the implied correlation is discussed in the Internet Appendix E.1. Panel A of Fig. 4 plots our daily expanded version of the quanto-implied risk premium. As reported in Panel B, controlling for daily variations in the quanto-implied risk premium over the full sample yields estimates of γ_κ that are very similar to those presented in Panel A.

As an alternative approach, we synthetically construct the daily quanto-implied risk premium building on the assumption that an investor holds a foreign riskless bond rather than a portfolio of domestic stocks, i.e., $R_{t+1} = R^{€}_{f,t}(S_{t+1}/S_t)$. As shown in Internet Appendix E.2, we can then directly use the risk-neutral variance of the exchange rate return to determine this synthetic version of the quanto-implied risk premium, which we illustrate in Panel B of Fig. 4. The risk-neutral variance can be inferred from the cross-section of currency option implied volatilities for different strikes using, for example, the methodology proposed by Britten-Jones and Neuberger (2000) or the method recently suggested by Martin (2017). We rely on one-year currency options, thus matching the maturity of the credit-implied risk premium, and employ the former (latter) methodology in Panel C (Panel D) of Table 4. Results are virtually identical in both cases, thereby confirming the exchange rate predictive ability of the credit-implied risk premium after accounting for daily fluctuations in the quanto-implied risk premium.[21]

4.3. Time-varying default probability

The previous section provides empirical evidence on the predictive ability of the credit-implied risk premium for the USD/EUR exchange rate. As highlighted in Eq. (9), exchange rate predictability arises exclusively from fluctuations in implied currency depreciation ($ICD_{i,t}$) since the risk-neutral probability of default ($\overline{\mathbb{Q}}_i$) is time-invariant. In this section, we verify that the risk-neutral probability of default does not contain any predictive information for exchange rate returns.

We start by showing that the risk-neutral probability of default is strongly related to global financial conditions,

[21] We present additional robustness exercises in the Internet Appendix. Table A.4 reports the estimates of γ_κ without controlling for X_t, whereas Tables A.5–A.6 use proxies of the quanto-implied risk premium based on different maturities of implied volatility. Results remain both qualitatively and quantitatively similar.

Table 5
Components of CRP and global financial conditions.
This table presents sample correlations between measures of global financial conditions and the first principal component of either the risk-neutral probability of defaults $\mathbb{Q}_{i,t}$ or the implied currency depreciation $ICD_{i,t}$ across countries. Measures of financial conditions include the CDX North American Investment Grade index, which reflects credit risk of US investment grade firms; the five-year Markit iTraxx Europe Senior Financials index, which reflects credit risk exposure of financial institutions in Europe; the one-year zero-coupon interest rate in dollar, as a proxy for bond market conditions; the year-on-year return on the S&P 500 and Euro Stoxx 50 indices, which reflect equity market performance in the US and Europe, respectively; the VIX and VSTOXX indices, which reflect equity option-implied uncertainty in the US and Europe, respectively; the VXY, which reflects aggregate option-implied uncertainty in the FX market; and the TED spread, which measures global funding liquidity conditions. We present results for the full sample (2010–2019), the European debt crisis (2010–2012), and the post-crisis period (2013–2019). The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

	Full sample 2010–2019		European debt crisis 2010–2012		Post debt crisis 2013–2019	
	$\mathbb{Q}_{i,t}$	$ICD_{i,t}$	$\mathbb{Q}_{i,t}$	$ICD_{i,t}$	$\mathbb{Q}_{i,t}$	$ICD_{i,t}$
CDX	−0.75	−0.14	−0.69	−0.06	−0.34	−0.22
iTraxx	−0.93	−0.22	−0.89	−0.18	−0.78	−0.39
Interest rate	−0.47	0.07	0.64	−0.01	−0.59	0.12
S&P 500	−0.11	−0.03	−0.58	−0.29	0.36	0.12
Euro Stoxx	−0.37	−0.02	−0.74	−0.14	0.37	0.08
VIX	0.51	−0.17	0.39	−0.39	−0.02	−0.09
VSTOXX	0.62	−0.16	0.59	−0.30	0.12	−0.17
VXY	0.48	−0.08	0.15	−0.40	0.18	0.07
TED spread	0.09	0.15	0.91	0.21	−0.41	0.12

while the implied currency depreciation is not. A principal component (PC) analysis, presented in Table A.7 and described in the Internet Appendix G, indicates a strong commonality in the country-level risk-neutral probability of default $\mathbb{Q}_{i,t}$, thus confirming existing evidence (e.g., Longstaff et al., 2011). As shown in Table 5, the first PC of $\mathbb{Q}_{i,t}$ is highly correlated with a variety of global financial conditions, both during and after the European sovereign debt crisis. Consistent with Doshi et al. (2017), our evidence suggests that a time-varying distress risk premium represents a sizable component of the risk-neutral default probability in Eurozone countries. In contrast, the first PC of $ICD_{i,t}$ comoves to a much lesser extent with the same set of variables. Aggregate risk-neutral probability of default in the Eurozone is thus highly correlated with global financial conditions, which are not expected to contain relevant information for exchange rate predictability.

We now provide evidence that the risk-neutral probability of default in the Eurozone does not help predict the USD/EUR exchange rate returns at any horizon. In this exercise, we first construct a counterfactual (or alternative) country-level measure of the credit-implied risk premium, $CRP^{alt}_{i,t}$, using time-varying risk-neutral probability of default ($\mathbb{Q}_{i,t}$) coupled with time-invariant (sample average) implied currency depreciation ($\overline{ICD}_i$) as

$$CRP^{alt}_{i,t} = \frac{b\mathbb{Q}_{i,t}}{R^{\$}_{f,t}}\left(\overline{ICD}_i - ECD_t\right), \tag{13}$$

which we then aggregate using Eq. (10) to obtain CRP^{alt}_t. Finally, we run predictive regressions similar to those presented in Eqs. (11)–(12) and then report estimates of the slope coefficient γ_κ in Table 6. Our results indicate that the counterfactual credit-implied risk premium $CRP^{\rm alt}_t$ has indeed no predictive power for the USD/EUR exchange rate return.[22]

We can thus conclude that accounting for time-variation in the risk-neutral probability of default would contaminate the credit-implied risk premium with information (e.g., related to global financial conditions) that contains no predictive value for exchange rate returns. Our analysis instead focuses on the predictive ability of the implied currency depreciation as the key driver of the credit-implied risk premium. This is the central contribution of this paper to the exchange rate predictability literature.

4.4. Additional analysis

We now summarize a set of additional results. First, we show that the credit-implied risk premium contains valuable information for predicting euro indices. Second, we provide evidence that our results are not driven by variations in global currency risk premia. Third, we study the determinants of the credit-implied risk premium and show that they differ fundamentally from those of the quanto-implied risk premium and sovereign CDS premium. Finally, we extend our analysis to emerging markets.

[22] As an additional analysis, Table A.8 in the Internet Appendix shows that the time-varying aggregate $\mathbb{Q}_t$ alone does not help predict the USD/EUR exchange rate. Results remain also similar when the credit-implied risk premium combines both time-varying risk-neutral probability of default and time-varying implied currency depreciation.

Table 6
FX predictability and counterfactual credit-implied risk premium.
This table presents results on the exchange rate predictive ability of the counterfactual credit-implied risk premium (CRP). The dependent variable is the daily average USD/EUR exchange rate return measured on a forecast horizon κ and expressed in annual terms. The counterfactual CRP, which we refer as CRP_t^{alt}, is constructed for the Eurozone using country-level time-varying risk-neutral probability of default ($\mathbb{Q}_{i,t}$) and country-level time-invariant (sample average) implied currency depreciations ($\overline{ICD}_i$) weighted by sovereign debt. Panel A presents the benchmark specification, which controls for the one-year interest rate differential between the US and Eurozone. Panel B (Panel C) adds global FX illiquidity and volatility (currency factors), whereas Panel D adds all control variables to the benchmark specification. We report p-values based on Hansen and Hodrick (1980) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using confidence intervals based on 1,000 stationary bootstrap repetitions (Politis and Romano, 1994). The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

	Panel A: Benchmark specification					*Panel B: Adding liquidity and volatility*				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t^{alt}	−0.065	−0.055	0.057	0.148	0.330	−0.169	−0.153	−0.024	0.044	0.204
	(0.839)	(0.850)	(0.813)	(0.620)	(0.133)	(0.643)	(0.611)	(0.911)	(0.850)	(0.121)
R^2 (%)	−0.06	0.09	1.41	4.11	19.83	−0.01	0.51	2.97	13.01	33.82
N	2,154	2,138	2,096	2,033	1,907	2,154	2,138	2,096	2,033	1,907
	Panel C: Adding currency factors					*Panel D: Adding all controls*				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t^{alt}	−0.065	−0.054	0.058	0.150	0.331	−0.178	−0.154	−0.024	0.046	0.204
	(0.841)	(0.854)	(0.779)	(0.542)	(0.103)	(0.629)	(0.612)	(0.903)	(0.828)	(0.120)
R^2 (%)	0.08	−0.13	1.28	4.01	19.69	0.15	0.30	2.87	12.95	33.78
N	2,154	2,138	2,096	2,033	1,907	2,154	2,138	2,096	2,033	1,907

Table 7
Predictability for different euro indices.
This table presents results on the euro index predictive ability of the credit-implied risk premium (CRP). The dependent variables is the daily average return on a selected euro index measured on a forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debt. Panels A and B use the trade-weighted and equally-weighted euro index, respectively, based on G10 currencies. Panels C and D use the same indices while excluding the dollar. Each specification controls for the one-year interest rate differential between the US and Eurozone, global FX illiquidity and volatility, and currency factors. We report p-values based on Hansen and Hodrick (1980) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using confidence intervals based on 1,000 stationary bootstrap repetitions (Politis and Romano, 1994). The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, ECB, and IHS Markit.

	Panel A: Trade-weighted euro index (with USD)					*Panel B: Equally-weighted euro index (with USD)*				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.315****	**2.061****	**1.707****	**1.488****	**0.993**	**2.211****	**1.940****	**1.610****	**1.414****	**0.944**
	(0.035)	(0.045)	(0.015)	(0.036)	(0.122)	(0.033)	(0.049)	(0.016)	(0.035)	(0.124)
R^2 (%)	1.63	5.22	10.75	10.71	8.89	1.74	5.32	11.09	10.97	9.28
N	2,146	2,130	2,088	2,025	1,899	2,146	2,130	2,088	2,025	1,899
	Panel C: Trade-weighted euro index (without USD)					*Panel D: Equally-weighted euro index (without USD)*				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.313****	**2.048****	**1.691****	**1.473****	**0.991**	**2.209****	**1.935****	**1.605****	**1.409****	**0.943**
	(0.038)	(0.047)	(0.017)	(0.042)	(0.131)	(0.034)	(0.050)	(0.017)	(0.037)	(0.127)
R^2 (%)	1.62	5.19	10.63	10.43	8.83	1.74	5.31	11.06	10.89	9.27
N	2,146	2,130	2,088	2,025	1,899	2,146	2,130	2,088	2,025	1,899

Alternative euro indices. Our analysis begs the question of whether the credit-implied risk premium contains valuable information for predicting the euro as opposed to dollar fluctuations. To this end, we explore the predictability of the credit-implied risk premium for a trade-weighted and an equally-weighted euro index, based on G10 currency pairs with and without the dollar. The Internet Appendix H describes the methodology and presents the key descriptive statistics.

We run predictive regressions based on Eq. (11) while using log returns on each euro index as the dependent variable. We report estimates of γ_κ in Table 7. Panels A and B employ indices that include the USD/EUR exchange rate and show strong evidence of exchange rate predictability, especially at the short horizon. In Panels C and D, we exclude the USD/EUR exchange rate from the composition of these indices but the coefficient estimates remain quantitatively and statistically very close to those reported in Panels A and B. These results confirm that the credit-implied risk premium contains relevant information for predicting the euro.

Global currency risk. A recent body of the literature shows that undiversifiable global risk plays a critical role for currency risk premia (e.g., Lustig et al., 2011). It is then

Table 8
Counterfactual analysis.
This table presents results on the predictive ability of the credit-implied risk premium (CRP) for other returns. The dependent variable is the daily average JPY/AUD exchange rate return (Panel A), the exchange rate return component of the carry strategy (Panel B), the return on the S&P 500 index (Panel C), and the trade-weighted dollar index against a basket of G10 currencies (Panel D) measured on a forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debt. Panel A controls for the one-year JPY-AUD interest rate differential, Panels B for the dollar factor, Panel C for the one-year interest rate differential between the US and Eurozone, and Panel D for the trade-weighted one-year interest rate differential between the dollar and the other G10 currencies. We report p-values based on Hansen and Hodrick (1980) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using confidence intervals based on 1,000 stationary bootstrap repetitions (Politis and Romano, 1994). The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

	Panel A: Predicting the JPY/AUD					*Panel B: Predicting the carry trade*				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t	1.308	1.147	0.718	0.469	0.193	−0.605	−0.455	−0.734	−0.857	−0.371
	(0.351)	(0.218)	(0.287)	(0.471)	(0.640)	(0.543)	(0.477)	(0.163)	(0.135)	(0.342)
R^2 (%)	0.19	0.84	1.04	1.18	2.48	0.26	0.12	2.36	7.86	4.00
N	2,154	2,138	2,096	2,033	1,907	2,154	2,138	2,096	2,033	1,907
	Panel C: Predicting the S&P 500					*Panel D: Predicting the dollar index*				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t	0.186	0.603	0.449	−0.216	0.175	0.059	−0.291	−0.387	−0.358	0.006
	(0.890)	(0.484)	(0.538)	(0.824)	(0.806)	(0.956)	(0.730)	(0.699)	(0.741)	(0.993)
R^2 (%)	−0.07	0.14	0.34	0.37	0.60	−0.01	0.37	1.24	2.35	6.71
N	2,154	2,138	2,096	2,033	1,907	2,146	2,130	2,088	2,025	1,899

important to verify that our credit-implied risk premium for the USD/EUR exchange rate captures risk related to the euro depreciation conditional upon default and is not another proxy for global risk. If the credit-implied risk premium captures variations in global risk premia, we should find similar evidence of predictability for other currency pairs and asset returns that are expected to fluctuate procyclically with aggregate economic conditions. To test this hypothesis, we run a simple counterfactual exercise that uses log returns on the JPY/AUD exchange rate and the S&P 500 index as dependent variables. As a complementary analysis, we also consider the carry trade strategy (daily exchange rate return component) and the log returns on the dollar index (trade-weighted index based on a basket of G10 currencies). The former is widely used as a proxy for global currency risk whereas the latter is expected to fluctuate counter-cyclically with aggregate economic conditions given its safe-haven status.

We run predictive regressions based on Eq. (11) where the set of independent variables includes the debt-weighted credit-implied risk premium for the Eurozone and the relevant interest rate differential. We report the results in Table 8 and find no evidence of exchange rate predictability in any of the counterfactual specifications. We can thus conclude that the credit-implied risk premium is unlikely to reflect variations in aggregate risk premia.[23]

Determinants of the credit-implied risk premium. We now study the determinants of the credit-implied risk premium, which we compare to those of the quanto-implied risk premium and of the sovereign CDS premium. We run daily contemporaneous regressions and report the estimates for different specifications in Table 9. For this exercise, we use the debt-weighted credit-implied risk premium, our daily version of the quanto-implied risk premium, and the debt-weighted, one-year, dollar-denominated sovereign CDS premium.

The credit-implied risk premium decreases with the level of economic uncertainty as measured by the VSTOXX (i.e., the one-month implied volatility of the EURO STOXX 50) and increases with economic activity, as measured by the year-on-year growth of industrial production for the Eurozone. The latter is available monthly and we retrieve daily observations by forward filling. As an alternative indicator, we use the Citi Economic Surprise Index for the Eurozone, which measures the pace at which economic indicators are coming in ahead of or below consensus forecasts. We also record a positive and statistically significant relationship with this indicator, thus confirming that the credit-implied risk premium is pro-cyclical relative to economic conditions. In contrast, quanto-implied and sovereign CDS premia are both countercyclical, being positively (negatively) correlated with the level of economic uncertainty (economic activity), in line with the properties of currency risk premia (Lustig et al., 2014).

Nominal conditions, as measured by the two-year German Bund yield, strongly impact all measures of risk but, interestingly, the sign is negative for the credit-implied risk premium and positive for the alternative measures of risk. Following a growing literature on the role of central bank communication for asset prices (e.g., Cieslak and Schrimpf, 2019), we disentangle ECB monetary news (i.e., news about monetary policy) and ECB economic news (i.e., news about economic growth and news affecting financial risk premia) using the direction of the comovement

[23] The results are similar whether we consider a trade-weighted or equally-weighted dollar index, with and without the euro in the currency basket. The same holds when using the Japanese yen index, constructed as a trade-weighted index based on the basket of G10 currencies, as the dependent variable.

Table 9
The determinants of credit-implied risk premium, quanto-implied risk premium, and sovereign CDS premium.
This table presents estimates of the determinants of different types of risk premia. The set of explanatory variables includes economic uncertainty (VSTOXX), economic growth (year-on-year growth of the industrial production for the Eurozone), economic surprise (Citi Economic Surprise Index for the Eurozone), Bund yield (German two-year bond yield), ECB monetary news (i.e., news about monetary policy) and ECB economic news (i.e., news about economic growth and news affecting financial risk premia) constructed akin to Cieslak and Schrimpf (2019). The credit-implied risk premium for the Eurozone is based on country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debt. The daily version of the quanto-implied risk premium is recovered by combining daily risk-neutral volatility and correlation components, i.e., one-year VIX index, one-year model-free USD/EUR option implied volatility akin to Britten-Jones and Neuberger (2000), and risk-neutral correlation inferred monthly (and kept constant intra-month) from the quanto forwards. The latter is replaced after October 2015 with the realized return correlation between the S&P 500 index and the USD/EUR exchange rate. Sovereign CDS premium for the Eurozone is constructed using country-level dollar-denominated CDS premia weighted by sovereign debts. We report p-values based on Newey and West (1987) standard errors in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg and IHS Markit.

	Credit-implied risk premium			Quanto-implied risk premium			Sovereign CDS premium		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Economic Uncertainty	−0.202***	−0.193***	−0.181***	0.078***	0.080***	0.041***	0.066***	0.067***	0.054***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Economic growth	0.141***	0.095	0.120**	−0.029	−0.039*	−0.127***	−0.042***	−0.045***	−0.074***
	(0.006)	(0.101)	(0.021)	(0.174)	(0.076)	(0.000)	(0.000)	(0.000)	(0.000)
Economic surprise		0.007*	0.007*		0.001	0.002**		0.001	0.001
		(0.058)	(0.057)		(0.141)	(0.023)		(0.301)	(0.212)
Bund yield (2y)			−0.360			1.257***			0.406***
			(0.243)			(0.000)			(0.000)
ECB monetary news × 2y			−1.297**			−0.078			−0.015
			(0.023)			(0.656)			(0.861)
ECB economic news × 2y			1.588**			0.198			0.051
			(0.015)			(0.539)			(0.740)
ECB news dummy			−0.364			0.011			0.017
			(0.233)			(0.864)			(0.681)
Constant	14.744***	14.610***	14.313***	−0.950***	−0.978***	0.062	−0.801***	−0.811***	−0.475***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.640)	(0.000)	(0.000)	(0.000)
R^2 (%)	18.7	19.3	19.7	24.4	24.7	64.2	47.9	48.0	58.8
N	2,225	2,225	2,225	2,225	2,225	2,225	2,225	2,225	2,225

between the stock market and Bund yield on the day of the news. We find that the relation between the credit-implied risk premium and the Bund yield is negative (positive) when ECB announcements essentially reflect monetary (economic and financial) news. In comparison, we find no such evidence for the other sources of risk. Overall, these results show that the credit-implied risk premium contains information that differs fundamentally from what is embedded in the quanto-implied risk premium and in the sovereign CDS premium.

Extension to emerging markets. We explore whether predictability goes beyond the USD/EUR exchange rate by extending our analysis to emerging markets. We consider five countries with sizable sovereign default risk and available sovereign CDS contracts denominated in both local currency and dollar. This set of countries consists of Mexico, Russia, South Africa, and Turkey, which covers diverse geographical regions and levels of economic development. For each country i, we first compute the credit-implied risk premium using dollar-denominated and local currency-denominated one-year CDS premia and then run panel regressions based on the following specification:

$$\Delta_\kappa s_{i,t+\kappa} = \alpha_{i,\kappa} + \tau_{t,\kappa} + \beta_\kappa IRD_{i,t} + \gamma_\kappa CRP_{i,t} + \varepsilon_{i,t+\kappa}, \quad (14)$$

where $s_{i,t}$ is the log of the nominal exchange rate on day t measured in units of dollar per currency i, $\Delta_\kappa s_{i,t+\kappa} = s_{i,t+\kappa} - s_{i,t}$ is the exchange rate return between days t and $t+\kappa$, $CRP_{i,t}$ is the credit-implied risk premium for currency i based on dollar-denominated and local currency-denominated one-year CDS premia observed on day t, and $IRD_{i,t}$ is the one-year interest rate differential between the dollar and currency i observed on day t. We complement our specification with currency fixed effects that control for time-invariant differences in exchange rate returns ($\alpha_{i,\kappa}$) and time fixed effects that control for unobservable time-variant global factors driving exchange rate returns ($\tau_{t,\kappa}$).[24] Table 10 presents the estimates of γ_κ for different forecast horizons κ ranging between one week and one year, with standard errors clustered at the daily level to account for potential serial correlation.

Panel A of Table 10 reports positive and statistically significant estimates of γ_κ between three-month and one-year horizons, thus implying that a country's $CRP_{i,t}$ positively predicts future local exchange rate returns. We reproduce the same exercise while excluding data when dollar-denominated CDS premia are lower than local-currency denominated CDS premia. These observations would imply a currency appreciation in default, at odds with the evidence that sovereign defaults tend to be associated with currency depreciation (Na et al., 2018). Panel B of Table 10 shows that the credit-implied risk premium continues to positively predict local currency returns after excluding these observations. Exchange rate return predictability of the credit-implied risk premium is, therefore,

[24] The panel is unbalanced and the sample period varies across countries. We describe data cleaning and report descriptive statistics in the Internet Appendix I.

Table 10
Analysis of emerging market currencies.
This table presents panel results on the exchange rate predictive ability of the credit-implied risk premium (CRP) for emerging markets, i.e., Mexico, Russia, South Africa, and Turkey. The dependent variable is the daily average exchange rate return against the US dollar measured on a forecast horizon κ and expressed in annual terms. CRP is constructed using country-level dollar-denominated and local currency-denominated one-year CDS premia. Panel A presents the benchmark specification, while Panel B excludes observations for which dollar-denominated CDS premia are lower than the local currency-denominated CDS premia. All specifications control for country-level one-year interest rate differential and include both time and country fixed effects. We report p-values based on standard errors clustered at the date level, in parenthesis. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. The sample (unbalanced) consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

	Panel A: Benchmark specification					*Panel B: Alternative specification*				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t	0.298**	0.151***	0.257***	0.297***	0.139***	0.526***	0.343***	0.456***	0.497***	0.256***
	(0.014)	(0.008)	(0.000)	(0.000)	(0.000)	(0.005)	(0.000)	(0.000)	(0.000)	(0.000)
R^2 (%)	35.15	35.89	32.82	39.75	46.26	34.97	35.76	32.82	40.26	46.61
N	7,673	7,630	7,484	7,279	6,832	7,613	7,570	7,424	7,219	6,772

also relevant for emerging countries, thus extending the paper's central findings beyond the Eurozone.

Other robustness exercises. We conduct additional tests that provide further robustness for our findings. First, we show that our predictability does not arise mechanically from the return persistence induced by overlapping observations. Second, we conduct a country-level study and verify that the predictability stemming from the credit-implied risk premium is concentrated among major and high-credit-risk Eurozone countries. Third, we show that our results are not driven by variations in counterparty risk. The results are presented and discussed in the Internet Appendix J.

5. The economic value of exchange rate predictability

This section examines the economic value of asset allocation strategies that exploit the out-of-sample predictive ability of the credit-implied risk premium for the USD/EUR exchange rate returns. In each period t, the investor takes two steps. First, she uses a predictive regression to forecast one-step ahead exchange rate returns. Second, depending on the forecasts of the model, she rebalances her portfolio by computing the new optimal weights (e.g., West et al., 1993; Fleming et al., 2001). Ultimately, we assess whether a portfolio strategy that conditions on the credit-implied risk premium performs better than a trading strategy based on the naïve random walk model, which is *de facto* the benchmark model to evaluate exchange rate predictability since the seminal contribution of Meese and Rogoff (1983). We first describe the framework and then present the empirical evidence based on weekly non-overlapping out-of-sample forecasts.

5.1. Out-of-sample forecasts

We sample exchange rates every Wednesday as in Burnside et al. (2007) and then produce out-of-sample forecasts using different specifications. The benchmark strategy builds on the driftless random walk (RW), which assumes that exchange rates are unpredictable. As competing strategies, we employ the random walk with drift (RW_d), the credit-implied risk premium (CRP), and the smoothed credit-implied risk premium (CRP_s). Below, we provide details on each strategy.

The CRP strategy builds on the following predictive regression:

$$\Delta s_t = \alpha + \gamma\, CRP_{t-1} + \varepsilon_t,$$

where Δs_t is the exchange rate return between weeks t and $t-1$ and CRP_{t-1} is the debt-weighted (or GDP-weighted) credit-implied risk premium observed on week $t-1$.[25] On each week t, we first estimate α and γ via least-squares using a one-year rolling window of weekly observations and then produce the conditional mean forecast as $\mathbb{E}_t[\Delta s_{t+1}] = \alpha + \gamma\, CRP_t$. For the conditional volatility forecast, we simply use the standard deviation of the regression residuals and set $\mathbb{V}_t[\Delta s_{t+1}] = \sigma_\varepsilon$. To mitigate parameter instability and day-of-week effects, we also run similar predictive regressions using the credit-implied risk premium smoothed (or averaged) over the previous week of daily observations, i.e., the CRP_s strategy. We plot in Fig. 5 the conditional mean forecasts against the USD/EUR exchange rate returns, aggregated at the monthly level and then standardized to have zero means and unit standard deviations to ease the comparison. A visual inspection reveals that our out-of-sample forecasts comove fairly well with future exchange rate returns.

We also impose economic sign restrictions before computing our conditional forecasts in the spirit of Campbell and Thompson (2008). In particular, on each week t, we set γ equal to zero whenever its estimate is negative, thus collapsing our conditional forecasts to those generated by a random walk with drift. Such restriction, moreover, would be consistent with the prediction of our theory and mitigate the parameter instability arising from using a short window of data.[26]

Moving to the driftless RW strategy, on each week t, the conditional mean is set equal to zero, whereas the condi-

[25] Exchange rate and CDS quotes may not be perfectly synchronized. We address this concern by sampling our credit-implied risk premium on each Tuesday of week $t-1$. In addition, lagging the predictor relative to the execution date by a business day makes the strategy more realistic as a portfolio manager may need some time to collect and process the data.

[26] The sign restrictions mostly apply from November 2012 to October 2013 and from November 2017 to April 2019.

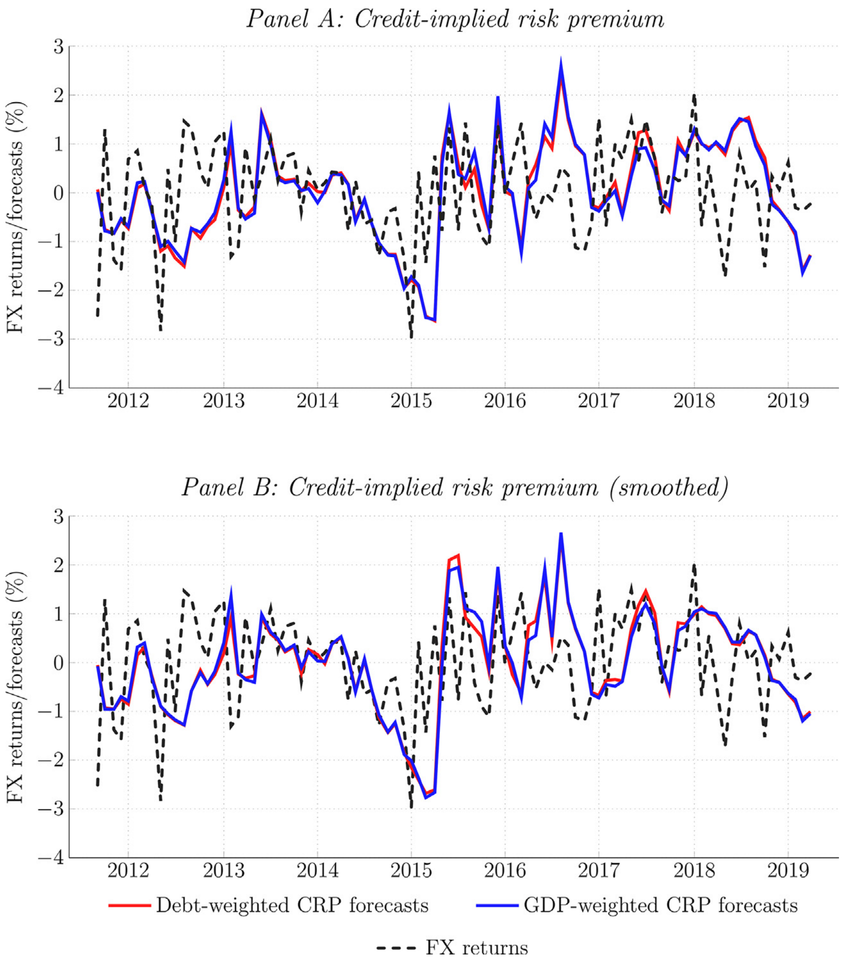

Fig. 5. Credit-implied risk premium and out-of-sample FX forecasts. *Note:* This figure displays the USD/EUR exchange rate returns and their out-of-sample forecasts based on a predictive regression estimated every Wednesday using a one-year rolling window of non-overlapping observations. The predictor is the credit-implied risk premium (CRP) in Panel A and the CRP smoothed (or averaged) over the past week in Panel B. Forecasts and exchange rate (FX) returns are aggregates within each calendar month and standardized to have zero means and unit standard deviations to ease the comparison. The sample consists of weekly observations between August 2011 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

tional volatility is computed as the one-year rolling standard deviation of the exchange rate returns. As an additional strategy, we also present results for the RW_d strategy. In this case, on each week t, the conditional mean and volatility forecasts are computed as the one-year rolling average and one-year rolling standard deviation, respectively, of the exchange rate returns.

5.2. Mean-variance framework

We consider a simple mean-variance asset allocation strategy whereby a US investor allocates her wealth between a domestic bond denominated in dollar and a foreign bond denominated in euro. While the domestic bond yields a riskless dollar return, the foreign bond delivers a risky dollar return that (in expectation) depends on the (expected) exchange rate return and the riskless foreign return. As a result, the only risk the US investor is exposed to is currency risk.

At each period t, our investor solves the following problem:

$$\max_{w_t} \quad \mathbb{E}_t[R_{p,t+1}] = w_t \mathbb{E}_t[R_{t+1}] + (1 - w_t) R^{\$}_{f,t}$$
$$\text{s.t. } \sigma^{\star}_p = w_t \mathbb{V}_t[R_{t+1}],$$

where $\mathbb{E}_t[R_{p,t+1}]$ is the conditional expectation of the gross portfolio return, $\mathbb{E}_t[R_{t+1}]$ is the conditional expectation of the gross risky return, $R^{\$}_{f,t}$ is the domestic gross riskless return, w_t is the weight on the risky asset, $\mathbb{V}_t[R_{t+1}]$ is the conditional volatility of R_{t+1}, and $\sigma^{\star}_p$ is the target volatility of the portfolio strategy. By construction, $\mathbb{E}_t[R_{t+1}] = \mathbb{E}_t[\Delta s_{t+1}] + R^{€}_{f,t}$ and $\mathbb{V}_t[R_{t+1}] = \mathbb{V}_t[\Delta s_{t+1}]$ as defined in the previous section, with $R^{€}_{f,t}$ denoting the gross foreign riskless return. The solution to this optimization problem delivers the risky asset weight in closed form (see, for example, Della Corte et al., 2009) and the investor's realized portfolio return at time $t+1$ equals $R_{p,t+1} = w_t R_{t+1} + (1 - w_t) R^{\$}_{f,t}$, where $R_{t+1} = \Delta s_{t+1} + R^{€}_{f,t}$.

5.3. Performance measures

We assess the economic value of exchange rate predictability with a set of standard mean-variance performance measures. We start with the performance fee of Fleming et al. (2001) that equates the average utility of the benchmark strategy b with the ones of the competing strategy c, where the latter is subject to expenses $\mathcal{F}$. Since the investor is indifferent between these strategies, $\mathcal{F}$ can be interpreted as the maximum performance fee she will pay to switch from the benchmark strategy (e.g., RW strategy) to the competing strategy (e.g., CRP strategy). We find the value of $\mathcal{F}$ that satisfies:

$$\sum_{t=0}^{T-1}\left\{[R_{c,t+1}-\mathcal{F}]-\eta[R_{c,t+1}-\mathcal{F}]^2\right\} = \sum_{t=0}^{T-1}\left\{R_{b,t+1}-\eta\left[R_{b,t+1}\right]^2\right\}, \quad (15)$$

where R_p is the gross portfolio return implied from the benchmark or competing strategy with $p=\{c,b\}$, and $\eta=\rho/(2+2\rho)$ is a constant that depends on the investor's degree of relative risk aversion ρ. Ultimately, this utility-based criterion measures how much a mean-variance investor is willing to pay for conditioning on better forecasts.

We also use the premium return difference that builds on the manipulation-proof performance measure of Goetzmann et al. (2007):

$$\mathcal{P}=\frac{1}{(1-\rho)}\left\{\ln\sum_{t=0}^{T-1}\left(\frac{R_{c,t+1}}{R^{\$}_{f,t}}\right)^{1-\rho}-\ln\sum_{t=0}^{T-1}\left(\frac{R_{b,t+1}}{R^{\$}_{f,t}}\right)^{1-\rho}\right\},$$

where $\mathcal{P}$ measures the risk-adjusted excess return an investor enjoys for using the information content of the competing strategy relative to the benchmark strategy and can be viewed as the maximum performance fee to switch from the benchmark to the competing strategy.[27]

We report both $\mathcal{F}$ and $\mathcal{P}$ in basis points (*bps*) per annum, while setting $\sigma_p^\star=10\%$ per annum and $\rho=6$. Different values of $\sigma_p^\star$ and ρ have qualitatively little impact on the asset allocation results. We also report commonly used measures of economic value, namely, the Sharpe ratio defined as $\mathcal{SR}_p=(\overline{R}_p-\overline{R}^{\$}_f)/\sigma_p$ and the Sortino ratio computed as $\mathcal{SO}_p=(\overline{R}_p-\overline{R}^{\$}_f)/\sigma_p^-$, where $\overline{R}_p$ is the average gross portfolio return, $\overline{R}^{\$}_f$ is the average lagged gross riskless rate, σ_p is the ex-post standard deviation of the portfolio returns, σ_p^- is the realized volatility of the negative portfolio returns. Both $\mathcal{SR}_p$ and $\mathcal{SO}_p$ for $p=\{c,b\}$ are reported in annual terms.[28]

[27] This criterion is robust to the distribution of portfolio returns and does not require the assumption of a particular utility function to rank portfolios, in contrast to $\mathcal{F}$ that assumes a quadratic utility function.

[28] The risk-adjusted performance of a competing strategy relative to its benchmark can be quantified with the risk-adjusted Sharpe ratio difference of Modigliani and Modigliani (1997), defined as $d\mathcal{SR}=\sigma_b(\mathcal{SR}_c-\mathcal{SR}_b)$. Similarly, we construct a risk-adjusted Sortino ratio difference as $d\mathcal{SO}=\sigma_b^-(\mathcal{SO}_c-\mathcal{SO}_b)$.

5.4. Impact of transaction costs

The impact of transaction costs is also important in assessing the profitability of dynamic trading strategies. We calculate the break-even proportional transaction cost, τ^{be}, that makes an investor indifferent between two alternative strategies (e.g., Han, 2006; Della Corte et al., 2009; Jondeau and Rockinger, 2012). If we assume that transaction costs are a fixed fraction of the value traded in the risky asset, the average weekly transaction cost of a given strategy can be computed as

$$\overline{\tau}_p=\frac{1}{T}\sum_{t=0}^{T-1}\left|w_{t+1}-w_t\frac{R_{t+1}}{R_{p,t+1}}\right| \quad (16)$$

and the break-even transaction cost is given by

$$\tau^{be}=\frac{\overline{R}_c-\overline{R}_b}{\overline{\tau}_c-\overline{\tau}_b} \quad (17)$$

such that an investor who pays transaction costs lower than τ^{be} will prefer the competing strategy to the benchmark one. Since τ^{be} is a proportional cost paid every time the portfolio is rebalanced, we report τ^{be} in *bps* per week.

5.5. Empirical evidence

Table 11 presents the out-of-sample performance of our portfolio strategies.[29] Panels A and B display results for the debt-weighted and GDP-weighted credit-implied risk premium, respectively. We find that, in both cases, exchange rate forecasts based on the credit-implied risk premium generate high economic value and outperform the benchmark strategy, with and without economic sign restrictions.[30] For example, the debt-weighted CRP strategy delivers a performance fee $\mathcal{F}$ of 294 *bps* per annum relative to the RW strategy. The same conclusion is reached with the premium return $\mathcal{P}$ of 297 *bps* per annum or the risk-adjusted performance $d\mathcal{SR}$ of 296 *bps* per annum (implied from $\mathcal{SR}$ and σ as described earlier), thus suggesting that quadratic utility characterizing the Fleming et al. (2001) criterion is not affecting our results. The CRP strategy also outperforms its benchmark in terms of downside risk as the implied $d\mathcal{SO}$ is equal to 349 *bps* per annum. Moreover, the performance of the CRP strategy improves when we mitigate parameter instability and day-of-week effects by backward smoothing our predictor: the debt-weighted CRP_s strategy delivers a performance fee $\mathcal{F}$ (premium return $\mathcal{P}$) of 391 (393) *bps* per annum relative to the RW strategy.

In the bottom panels, we impose economic restrictions on the coefficient estimates of the predictive regressions in the spirit of Campbell and Thompson (2008) and find slightly better results. In particular, we set γ equal to zero whenever its estimate is negative and find that the debt-weighted CRP (CRP_s) strategy achieves a performance

[29] The bond interest rates are proxied with one-week eurodeposit rates (while setting negative rates equal to zero). In Table A.13 in the Internet Appendix, we relax this restriction and results remain largely comparable.

[30] In our sample, the RW_d strategy underperforms RW strategy. A possible explanation is that the constant term is difficult to estimate with precision, especially with a short window of data.

Table 11
Economic value of exchange rate predictability: Out-of-sample analysis.
This table presents the economic value of asset allocation strategies that exploit the out-of-sample USD/EUR exchange rate predictability. The benchmark model is the naïve random walk (RW), whereas the competing models (Z) are the random walk with drift (RW_d), the credit-implied risk premium (CRP), and the credit-implied risk premium smoothed (or averaged) over the past week (CRP_s). Using out-of-sample conditional forecasts from each model, a US investor maximizes her expected return strategy subject to a target volatility of 10% per annum while allocating wealth between a dollar-denominated bond and a euro-denominated bond whose expected return is risky in dollar terms. We denote by Δs_{t+1} the USD/EUR exchange rate return between weeks $t+1$ and t. We report the percentage mean μ, percentage volatility σ, Sharpe ratio $\mathcal{SR}$, and Sortino ratio $\mathcal{SO}$ in annual terms. $\mathcal{F}$ denotes the performance fee a risk-averse investor is willing to pay for switching from the RW to a competing strategy. $\mathcal{P}$ is the premium return generated by a given strategy relative to the RW. $\mathcal{F}$ and $\mathcal{P}$ are computed for a degree of relative risk aversion equal to 6 and are expressed in annual basis points. τ^{be} is the break-even proportional transaction cost a given strategy relative to the RW, expressed in weekly basis points. The conditional forecasts are based on predictive regressions re-estimated every Wednesday using a one-year rolling window of non-overlapping observations. Constrained predictability indicates that the out-of-sample forecasts are subject to an economic sign restriction in the spirit of Campbell and Thompson (2008). Interest rates are proxied with one-week eurodeposit rates (with negative rates set equal to zero). The sample consists of weekly non-overlapping observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

	Panel A: Debt-weighted CRP							Panel B: GDP-weighted CRP						
	μ	σ	$\mathcal{SR}$	$\mathcal{SO}$	$\mathcal{F}$	$\mathcal{P}$	τ^{be}	μ	σ	$\mathcal{SR}$	$\mathcal{SO}$	$\mathcal{F}$	$\mathcal{P}$	τ^{be}
No predictability: Benchmark specification														
RW	3.32	10.18	0.26	0.42				3.32	10.18	0.26	0.42			
Unconstrained predictability: $\mathbb{E}_t[\Delta s_{t+1}] = \alpha + \gamma Z_t$														
RW_d	2.10	10.35	0.14	0.23	−133	−132	−200	2.10	10.35	0.14	0.23	−133	−132	−200
CRP	6.40	10.39	0.55	0.97	294	297	24	7.18	10.38	0.63	1.11	373	375	34
CRP_s	7.36	10.38	0.64	1.08	391	393	46	7.21	10.36	0.63	1.07	377	379	47
Constrained predictability: $\mathbb{E}_t[\Delta s_{t+1}] = \alpha$ when $\gamma < 0$														
CRP	6.26	9.63	0.58	1.03	326	329	25	6.97	9.56	0.66	1.17	401	404	33
CRP_s	8.07	10.00	0.74	1.27	485	487	53	7.11	9.97	0.65	1.09	391	393	43

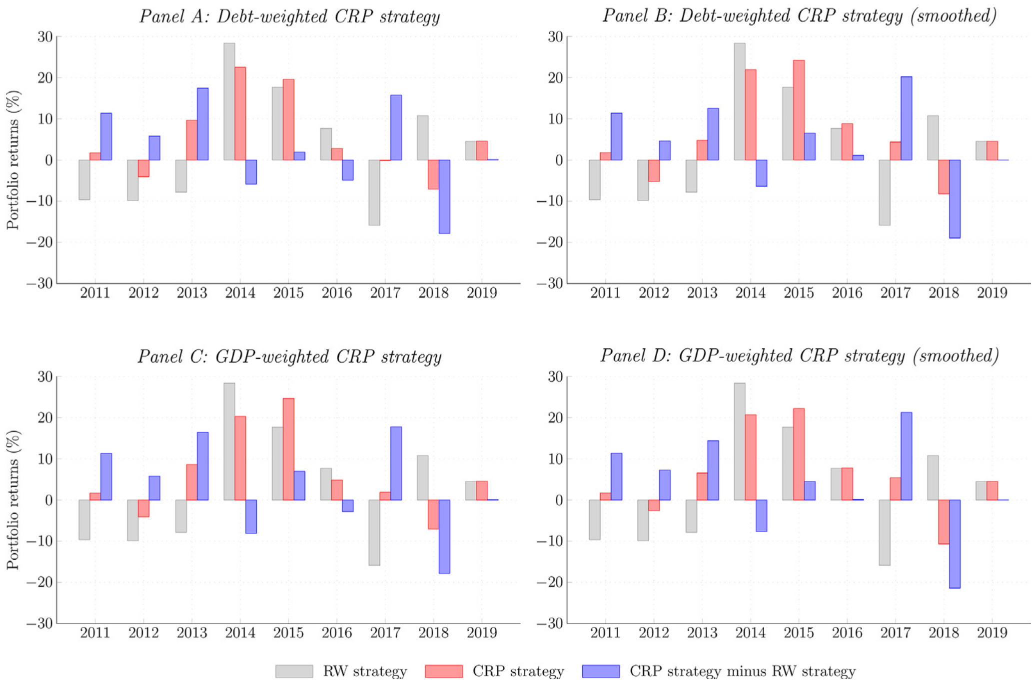

Fig. 6. Credit-implied risk premium and out-of-sample returns. *Note:* This figure displays the out-of-sample portfolio returns of an asset allocation strategy that exploits the predictability of the USD/EUR exchange rate return. A US investor employs weekly forecasts and allocates wealth between a dollar- and euro-denominated short-term bond, seeking to maximize expected return subject to target volatility of 10% per annum. The predictive regressions are re-estimated every Wednesday using a one-year rolling window of non-overlapping observations. The predictor is the credit-implied risk premium (CRP) in Panels A and C, and the CRP smoothed (or averaged) over the past week in Panels B and D. The benchmark model is the naïve random walk (RW). Interest rates are proxied with one-week eurodeposit rates. The sample consists of weekly observations between August 2011 and April 2019. Returns are cumulated within each calendar year. Data are from Bloomberg, Datastream, and IHS Markit.

Table 12
Economic value of exchange rate predictability: Bootstrap exercise.
This table presents the statistical significance of the performance measures reported in Table 11. The benchmark model is the naïve random walk (RW) whereas the competing models (Z) are the random walk with drift (RW_d), the credit-implied risk premium (CRP), and the credit-implied risk premium smoothed (or averaged) over the past week (CRP_s). Using out-of-sample conditional forecasts from each model, a US investor maximizes her expected return strategy subject to a target volatility of 10% per annum while allocating wealth between a dollar-denominated bond and a euro-denominated bond whose expected return is risky in dollar terms. We denote by Δs_{t+1} the USD/EUR exchange rate return between weeks $t+1$ and t. We report the percentage p-value computed using 10,000 bootstrap replications generated under the null of no predictability as in Mark (1995) and Kilian (1999). The algorithm, summarized in the Internet Appendix F.2, employs a restricted VAR under the null of no predictability. $d\mathcal{SR}$ and $d\mathcal{SO}$ are the volatility-adjusted Sharpe ratio and Sortino ratio difference, respectively, between a competing model and the RW. $\mathcal{F}$ denotes the performance fee a risk-averse investor is willing to pay for switching from the RW to a competing strategy. $\mathcal{P}$ is the premium return generated by a given strategy relative to the RW. $\mathcal{F}$ and $\mathcal{P}$ are computed for a degree of relative risk aversion equal to 6. τ^{be} is the break-even proportional transaction cost a given strategy relative to the RW. The conditional forecasts are based on predictive regressions re-estimated every Wednesday using a one-year rolling window of non-overlapping observations. Constrained predictability indicates that the out-of-sample forecasts are subject to an economic sign restriction in the spirit of Campbell and Thompson (2008). Interest rates are proxied with one-week eurodeposit rates (with negative rates set equal to zero). The sample consists of weekly non-overlapping observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

	Panel A: Debt-weighted CRP					*Panel B: GDP-weighted CRP*				
	$d\mathcal{SR}$	$d\mathcal{SO}$	$\mathcal{F}$	$\mathcal{P}$	τ^{be}	$d\mathcal{SR}$	$d\mathcal{SO}$	$\mathcal{F}$	$\mathcal{P}$	τ^{be}
Unconstrained predictability: $\mathbb{E}_t[\Delta s_{t+1}] = \alpha + \gamma Z_t$										
RW_d	29.03	29.59	30.89	30.87	93.69	29.03	29.59	30.89	30.87	93.69
CRP	4.49	4.31	4.58	4.47	4.26	3.30	3.00	3.26	3.23	2.63
CRP_s	2.18	2.62	2.18	2.18	1.85	3.13	3.28	3.13	3.13	2.33
Constrained predictability: $\mathbb{E}_t[\Delta s_{t+1}] = \alpha$ when $\gamma < 0$										
CRP	2.04	1.87	2.23	2.22	2.79	1.88	1.66	2.09	2.07	2.53
CRP_s	0.81	0.92	0.89	0.90	0.99	1.89	1.85	2.10	2.10	2.06

fee of 326 (485) *bps* per annum relative to the benchmark strategy. The empirical evidence, moreover, remains qualitatively similar when using the GDP-weighted credit-implied risk premium.

Finally, if transaction costs are sufficiently high, the period-by-period fluctuations in the portfolio weights will render the exercise too costly to implement relative to the RW model. For the unconstrained debt-weighted CRP strategy, a US investor would switch back to the RW strategy if she pays a proportional transaction cost higher than 24 *bps* per week when exploiting the CRP strategy. The τ^{be} increases when smoothing our predictor and imposing economic restrictions on coefficient estimates of the predictive regressions. By and large, these values remain reasonably high and unlikely to be hit by professional FX traders.

5.6. Further analysis

We now present a number of additional exercises that further corroborate the evidence discussed above. In Fig. 6, we aggregate weekly portfolio returns by calendar year and display the annual performance of each strategy. We find that the debt-weighted CRP strategy outperforms the RW strategy six out of nine times (Panel A), whereas the debt-weighted CRP_s strategy outperforms the RW strategy seven out of nine times (Panel B). Conditioning on the credit-implied risk premium, therefore, generates tangible out-of-sample economic gains to an investor that uses exchange rate forecasts within an active portfolio strategy, and these economic gains tend to be spread across multiple years.

In Table 12, we present evidence on the statistical significance of the performance measures associated with our portfolio strategies. We build on Mark (1995) and Kilian (1999) and generate 10,000 artificial samples under the null of no predictability. This procedure, which we describe in Internet Appendix F.2, preserves the autocorrelation structure of the predictive variable and maintains the cross-correlation structure of the residuals.[31]

We report the percentage bootstrapped p-values for different measures of economic value and different specifications. In contrast to the RW_d strategy, the performance measures associated with the CRP strategies have p-values below the conventional 5% level. In the top panel of Table 12, for example, we employ unrestricted out-of-sample forecasts and show that the percentage p-values for the debt-weighted CRP strategy is equal to 4.58 for the performance fee $\mathcal{F}$ and 4.47 for the premium return $\mathcal{P}$. Results further improve when using the debt-weighted CRP_s strategy or imposing economic sign restrictions.

Finally, we check whether the out-of-sample forecasts based on the credit-implied risk premium relate to currency traders' order flow, which summarizes how traders act on their expectations. We proxy currency traders' order flow with the net positions of speculators in the fu-

[31] The data generating process under the null of no predictability employs a restricted vector autoregressive process to reduce the number of unknown parameters to estimate. Table A.14 in the Internet Appendix relaxes these restrictions and reports fairly similar results.

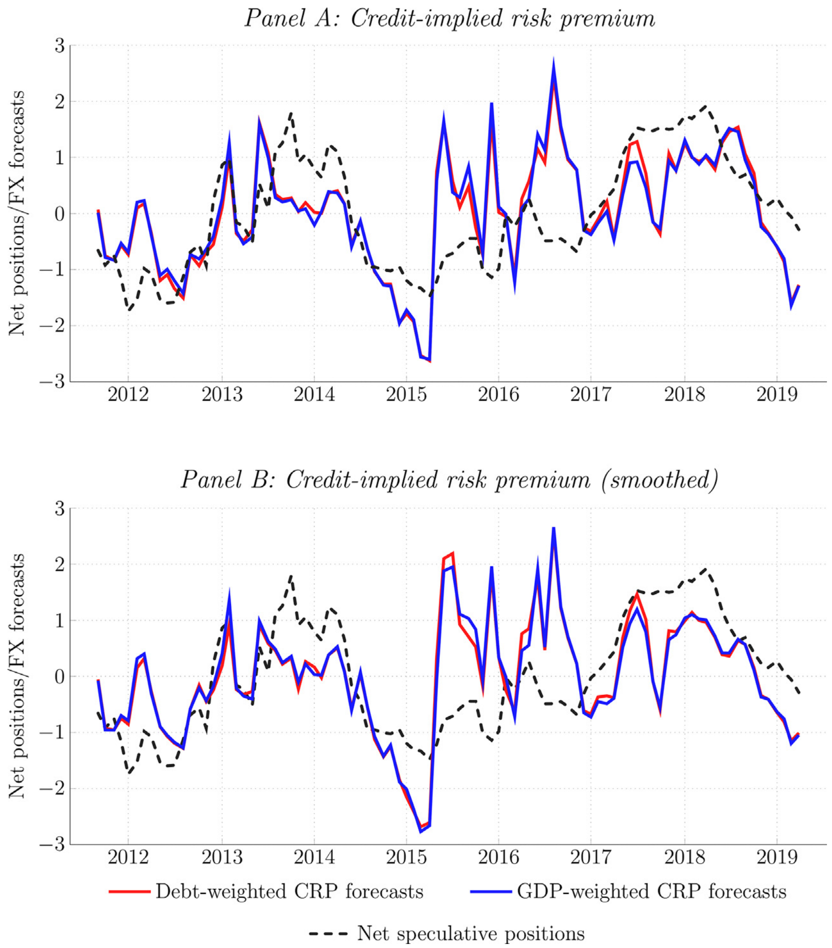

Fig. 7. Credit-implied risk premium and speculative positions. *Note:* This figure displays the net speculative positions for currency futures and the out-of-sample return forecasts, both on the USD/EUR exchange rate. The net speculative positions are measured as the difference between long and short positions of non-commercial traders (i.e., managed funds and institutional investors) scaled by the total open interest from the Commitments of Traders (COT) positions. The forecasts are based on a predictive regression estimated every Wednesday using a one-year rolling window of non-overlapping observations. The predictor is the credit-implied risk premium (CRP) in Panel A and the CRP smoothed (or averaged) over the past week in Panel B. The sample consists of weekly observations between August 2011 and April 2019. Forecasts and net positions are aggregated within each calendar month and standardized to have zero means and unit standard deviations to ease comparison. Futures positions are from the website of the US Commodity Futures Trading Commission (CFTC). Other data are from from Bloomberg, Datastream, IHS Markit.

tures market (see Section 3.3 for additional details) and uncover a positive and statistically significant relationship between the net speculative positions and our lagged out-of-sample exchange rate forecasts (see Table A.15 in the Internet Appendix). This link can be visualized clearly in Fig. 7, which plots exchange rate forecasts and net speculative positions, aggregated at the monthly frequency and standardized to have zero means and unit standard deviations to ease the comparison. This analysis confirms that the predictive information arising from the credit-implied risk premium positively correlates with currency traders' expectations and, thus, with their positions in the foreign exchange market.

6. Conclusion

This paper uncovers, both theoretically and empirically, a novel source of currency risk premium, which we label the *credit-implied risk premium*. This risk premium component reflects investors' risk-neutral expectations about currency movements conditional on a sovereign default, which is a severe but rare event. We exploit dual-currency sovereign CDS to derive a market-based measure of the expected currency depreciation conditional on sovereign default, using daily data over the period 2010–2019.

We find that an aggregate measure of the credit-implied risk premium for the Eurozone positively predicts future USD/EUR exchange rate returns at various horizons, even after controlling for the interest rate differential, the quanto-implied risk premium of Kremens and Martin (2019), FX liquidity and volatility, and traditional currency factors. The predictability indicates that investors are compensated for bearing the risk of currency depreciation in the event of a sovereign default. Our predictor, moreover, generates tangible economic gains to an investor using dynamic forecasts in active portfolio management. We obtain strong economic evidence against the naïve random walk benchmark using a sample of weekly non-overlapping observations, and our results are robust to reasonably high transaction costs. Overall, the credit-implied risk premium appears to be a critical driver of exchange rate returns, and we provide evidence that investors can benefit from this new source of information.

Declaration of Competing Interest

I have no potential conflicts to disclose.

Data availability

We have prepared a folder with data (except the raw CDS data). https://data.mendeley.com/datasets/fzz8g9757k/1.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jfineco.2023.06.002

References

Andrews, D.W.K., 1991. Heteroskedasticity and autocorrelation consistent covariance matrix estimation. Econometrica 59 (3), 817–858.
Ang, A., Bekaert, G., 2007. Stock return predictability: is it there? Rev. Financ. Stud. 20 (3). 651–07
Augustin, P., 2018. The term structure of CDS spreads and sovereign credit risk. J. Monet. Econ. 96, 53–76.
Augustin, P., Chernov, M., Song, D., 2020. Sovereign credit risk and exchange rates: Evidence from CDS quanto spreads. J. Financ. Econ. 137 (1), 129–151.
BIS, 2019. Triennial central bank survey of foreign exchange and over-the–counter derivatives markets in 2019. Bank for International Settlements, Basel.
Britten-Jones, M., Neuberger, A., 2000. Option prices, implied price processes, and stochastic volatility. J. Finance 55 (2), 839–866.
Buraschi, A., Menguturk, M., Sener, E., 2015. The geography of funding markets and limits to arbitrage. Rev. Financ. Stud. 28 (4), 1103–1152.
Burnside, C., Eichenbaum, M., Kleshchelski, I., Rebelo, S., 2011. Do peso problems explain the returns to the carry trade? Rev. Financ. Stud. 24 (3), 853–891.
Burnside, C., Eichenbaum, M., Rebelo, S., 2007. The returns to currency speculation in emerging markets. Am. Econ. Rev. 97 (2), 333–338.
Campbell, J.Y., Thompson, S.B., 2008. Predicting excess stock returns out of sample: can anything beat the historical average? Rev. Financ. Stud. 21 (4), 1509–1531.
Cieslak, A., Schrimpf, A., 2019. Non-monetary news in central bank communication. J. Int. Econ. 118, 293–315.
Corradin, S., Rodriguez-Moreno, M., 2014. Limits to arbitrage: empirical evidence from euro area sovereign bond markets. Working Paper, European Central Bank.
De Santis, R.A., 2019. Redenomination risk. J. Money Credit Bank. 51 (8), 2173–2206.
Della Corte, P., Ramadorai, T., Sarno, L., 2016. Volatility risk premia and exchange rate predictability. J. Financ. Econ. 120 (1), 21–40.
Della Corte, P., Riddiough, S.J., Sarno, L., 2016. Currency risk premia and global imbalances. Rev. Financ. Stud. 29 (8), 2161–2193.
Della Corte, P., Sarno, L., Schmeling, Wagner, C., 2022. Exchange rates and sovereign risk. Manag. Sci.,. Forthcoming
Della Corte, P., Sarno, L., Tsiakas, I., 2009. An economic evaluation of empirical exchange rate models. Rev. Financ. Stud. 22 (9), 3491–3530.
Doshi, H., Jacobs, K., Zurita, V., 2017. Economic and financial determinants of credit risk premiums in the sovereign CDS market. Rev. Asset Pric. Stud. 7 (1), 43–80.
Du, W., Schreger, J., 2016. Local currency sovereign risk. J. Finance 71 (3), 1027–1070.
Ehlers, P., Schoenbucher, P., 2004. The influence of FX risk on credit spreads. Working Paper, ETH Zürich.
Elizalde, A., Doctor, S., Singh, H., 2010. Trading credit in different currencies via quanto CDS. Technical Report. JP Morgan.
Engel, C., West, K., 2005. Exchange rates and fundamentals. J. Polit. Econ. 113 (3), 485–517.
Fama, E.F., 1984. Forward and spot exchange rates. J. Monet. Econ. 14 (3), 319–338.
Fleming, J., Kirby, C., Ostdiek, B., 2001. The economic value of volatility timing. J. Finance 56 (3), 329–352.
Goetzmann, W., Ingersoll, J., Spiegel, M., Welch, I., 2007. Portfolio performance manipulation and manipulation-proof performance measures. Rev. Financ. Stud. 20 (5), 1503–1546.
Han, Y., 2006. Asset allocation with a high dimensional latent factor stochastic volatility model. Rev. Financ. Stud. 19 (1), 237–271.
Hansen, L., Hodrick, R., 1980. Forward exchange rates as optimal predictors of future spot rates: an econometric analysis. J. Polit. Econ. 88 (5), 829–853.
Herz, B., Tong, H., 2008. Debt and currency crises: complements or substitutes? Rev. Int. Econ. 16 (5), 955–970.
ISDA, 2003. ISDA credit derivative definition. Int. Swaps Derivat. Assoc..
Jondeau, E., Rockinger, M., 2012. On the importance of time variability in higher moments for asset allocation. J. Financ. Econom. 10 (1), 84–123.
Karnaukh, N., Ranaldo, A., Söderlind, P., 2015. Understanding FX liquidity. Rev. Financ. Stud. 28 (11), 3073–3108.
Kilian, L., 1999. Exchange rates and monetary fundamentals: what do we learn from long-horizon regressions? J. Appl. Econom. 14 (5), 491–510.
Kremens, L., 2022. Currency redenomination risk. Journal of Financial and Quantitative Analysis. forthcoming.
Kremens, L., Martin, I., 2019. The quanto theory of exchange rates. Am. Econ. Rev. 109 (3), 810–843.
Lando, D., Bang Nielsen, A., 2018. Quanto CDS spreads. Working Paper, Copenhagen Business School.
Longstaff, F.A., Pan, J., Pedersen, L.H., Singleton, K.J., 2011. How sovereign is sovereign credit risk? Am. Econ. J.: Macroecon. 3 (2), 75–103.
Lustig, H., Roussanov, N., Verdelhan, A., 2011. Common risk factors in currency markets. Rev. Financ. Stud. 24 (11), 3731–3777.
Lustig, H., Roussanov, N., Verdelhan, A., 2014. Countercyclical currency risk premia. J. Financ. Econ. 111 (3), 527–553.
Mano, R., 2013. Exchange rates upon sovereign default. Working Paper, International Monetary Fund.
Mark, N.C., 1995. Exchange rates and fundamentals: evidence on long-horizon predictability. Am. Econ. Rev. 85 (1), 201–218.
Martin, I., 2017. What is the expected return on the market? Q. J. Econ. 132 (1), 367–433.
Meese, R.A., Rogoff, K., 1983. Empirical exchange rate models of the seventies: Do they fit out of sample? J. Int. Econ. 14 (1–2), 3–24.
Menkhoff, L., Sarno, L., Schmeling, M., Schrimpf, A., 2012. Carry trades and global foreign exchange volatility. J. Finance 67 (2), 681–718.
Modigliani, F., Modigliani, L., 1997. Risk-adjusted performance. J. Portfolio Manag. 23 (Winter), 45–54.
Na, S., Schmitt-Grohé, S., Uribe, M., Yue, V., 2018. The twin Ds: optimal default and devaluation. Am. Econ. Rev. 108 (7), 1773–1819.
Newey, W., West, K., 1987. A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. Econometrica 55 (3), 703–708.
Politis, D.N., Romano, J.P., 1994. The stationary bootstrap. J. Am. Stat. Assoc. 89 (428), 1301–1313.
Reinhart, C.M., 2002. Default, currency crises and sovereign credit ratings. World Bank Econ. Rev. 16 (2), 151–170.
West, K.D., Edison, H.J., Cho, D., 1993. A utility-based comparison of some models of exchange rate volatility. J. Int. Econ. 35 (1–2), 23–45.